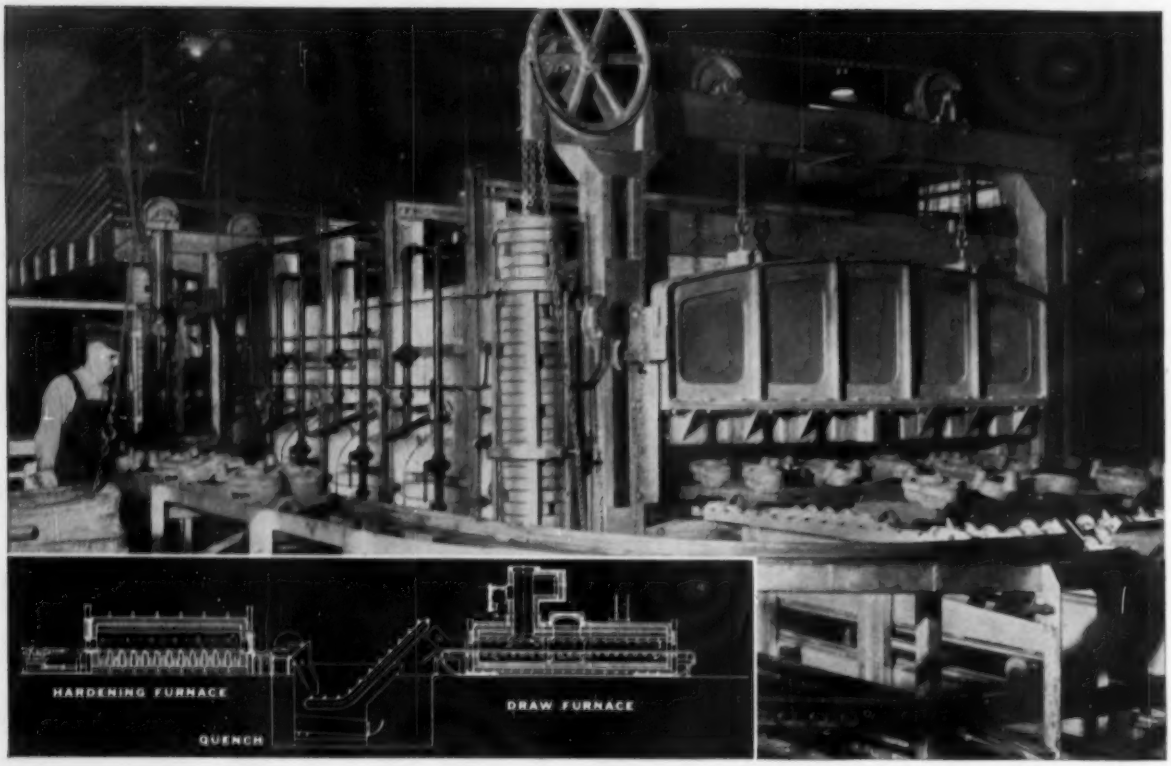
metal
HOT STEEL
PROGRESS
SAFETY FIRST
CAUTION
DO NOT WATCH
THE ARC
NOTICE
SOME FORM OF EYE
PROTECTION MUST
BE WORN WHILE IN
HIS DEPARTMENT
MEN
WORKING
ABOVE



NO REJECTS IN 6 MONTHS!

direct-fired automatic furnace line handles over 3,000 lbs./hr. of varied production

Let's repeat that. Not a reject in 6 months—even when customers requested more uniform microstructures in steel forgings, and faster delivery, from this big job shop. In addition, they achieved lower unit, operating, and labor costs with more versatile production . . . all in their 'Surface'-built automatic heat treat line. This line is a fine example of the advantages of 'Surface' direct-fired furnaces and furnace equipment:

UNIFORM QUALITY. Brinell readings on samples from the hardening and draw furnaces have been extremely consistent with close tolerances.

HIGH PRODUCTION. Actual production rate has been as high as 3,600 lbs./hr. of work, heated from cold to 1550F—even better than design capacity.

LOW OPERATING COST. Combustion efficiency stems from 'Surface' automatic proportioning, one-valve burners.

LOW LABOR COST. The photo shows part of the conveyor system which enables one man to run the whole line. Formerly, the job required 3 men.

The high-temperature convection draw furnace on this line has an operating range of 800-1350F, permitting processing of steels ranging from SAE 1041 to SAE 8640.

Write for Literature H54-1; see how these "work-horse" furnaces can pay off for you.

Surface
HEAT TREATING EQUIPMENT

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

ALSO MAKERS OF *Kathabar* HUMIDITY CONDITIONING *Janitrol* AUTOMATIC SPACE HEATING

Metal Progress

Volume 67, No. 5

May . . 1955

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Cover Design by STEVE NOVAK

Engineering Articles

Fatigue and the Comet Disasters, by Tom Bishop 79
The British inquiry into the cause of disasters to jet-propelled air liners will doubtless remain a classic for all investigators of structural failures. It appears probable that, at a high altitude, a tiny fatigue crack initiated catastrophic failure of the cabin wall and the pressurized cabin literally exploded.

Cast Bolts for Pipe Joints, by C. K. Donoho 86
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Arc-Cast Molybdenum – Ingot to Bar, Sheet or Wire, by N. L. Deuble 89
Hot ingots are covered with slippery molten oxide and extrusion is better than forging for initial reductions. Further rolling to bars and sheet, hot swaging to rod, and hot drawing in diamond dies give little difficulty.

Electroplating on Aluminum, by R. F. Hafer 93
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A Microscope Hot Stage, by H. A. Saller, R. F. Dickerson and R. J. Carlson 105
A compact unit for studying structural changes in metals at temperatures up to 1800° F. Description covers vacuum furnace, optical group, cold trap and vacuum system.

Welding Cracks in Columbium-Bearing Stainless Steel 109
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Lubricants for Titanium, by Ernest Rabinowicz and E. P. Kingsbury 112
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Hydrogen Embrittlement of Titanium Alloys, Report of an Investigation by Harris M. Burte, Eugene F. Erbin, George T. Hahn, Ralph J. Kotfila, John W. Seeger and Donald A. Wruck 115
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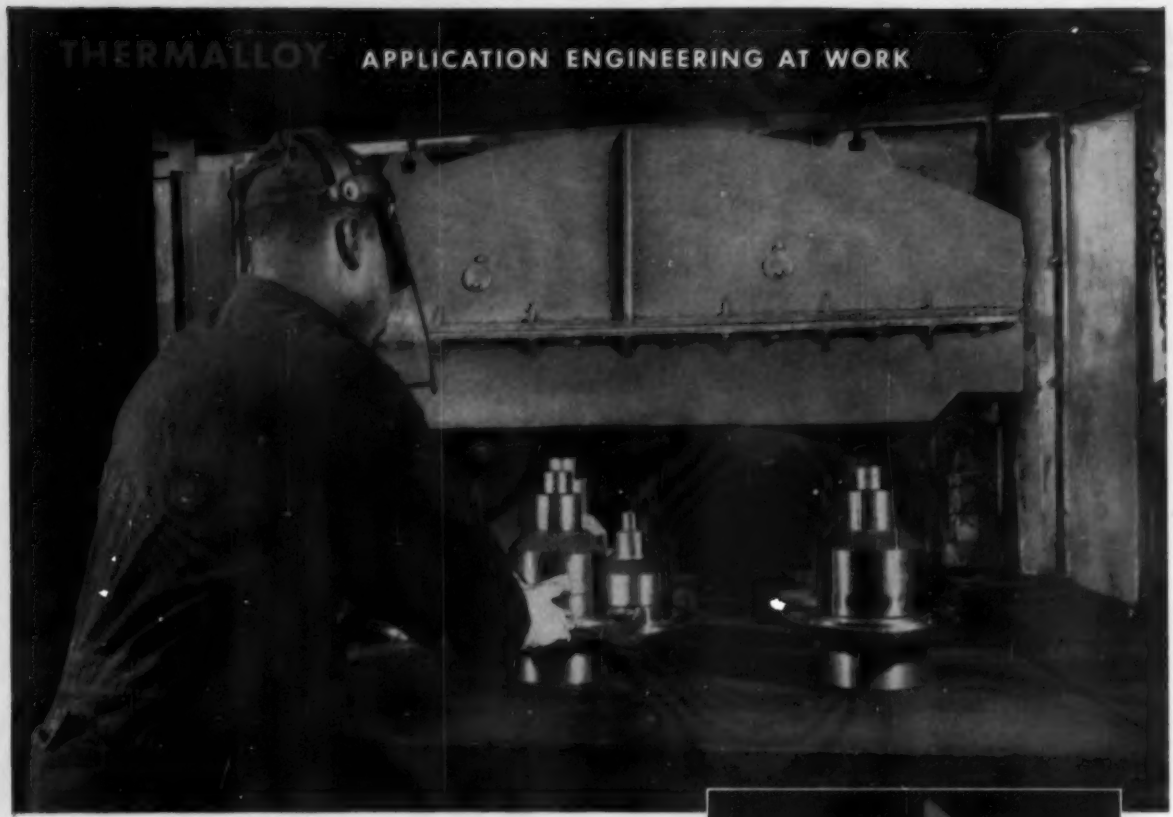

specify THERMALLOY FURNACE CONVEYOR BELTS for heavier loads at high heat

This partially assembled belt section shows the short integral cast pins that eliminate "crank shafting" in Thermalloy heavy-duty conveyor belt installations.

55″ wide on bearing centers of 32′, this new furnace conveyor belt at Commonwealth Industries, Inc., Detroit, carries over 35 lbs. per sq. ft. in normal service. At times, a total of 5,000 lbs. and more is loaded on the belt. And it's versatile! Work ranges from ½ lb. to 100 lbs. per piece, temperatures up to 1650°.

Here was the problem. Commonwealth, modern commercial heat-treater for the automotive industry, needed a belt which could carry small and large parts to be heat-treated, in volume. They asked Electro-Alloys to help. Starting with the Thermalloy heavy-duty belt design, Electro-Alloys engineers designed special side links to keep the small work from rolling off into the furnace bed. The results have been higher production at less cost for Commonwealth, and another successful case history of Thermalloy application engineering at work.

Our permanent staff of engineers is ready to help *you* design, improve or modernize the alloy in your heat-treating installations. Thermalloy heat-resistant alloys are cast for many furnace and other heat-treat applications. Write us in Elyria, Ohio, for Conveyor Belt Bulletin T-241, or call any of the sales offices listed below.

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Critical Points

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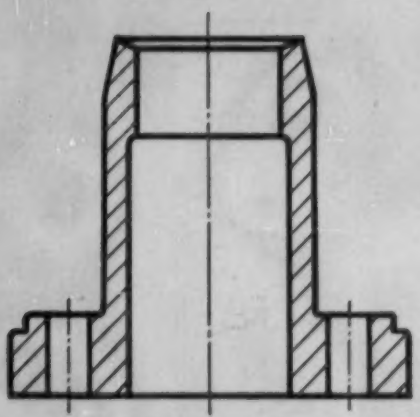
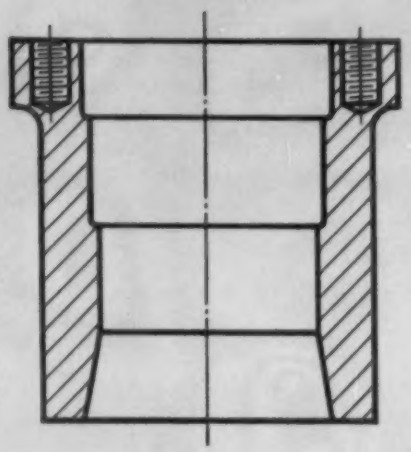
HOW TO MAKE RING-SHAPED TOOL STEEL PARTS FASTER AND EASIER

FORMING AND PIERCING DIE



BLANKING AND FORMING DIE



Graph-Mo Hollow-Bar comes in sizes from 4 to 16 inches O. D. with various wall thicknesses. Immediate delivery on many sizes from warehouses of the distributors, A. Milne Co. and Peninsular Steel Company.

New GRAPH-MO HOLLOW-BAR® eliminates drilling— and machines 30% faster

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On top of that, the rest of the machining's faster—30% faster, compared to other tool steels. That's because Graph-Mo has free graphite in its structure. It means less tendency to pick up, scuff and gall, too.

That same graphite plus diamond-hard carbides give Graph-Mo amazing wear resistance. Users have written us that Graph-Mo outwears other tool steels, on the average, three to one!

Graph-Mo responds uniformly to heat treatment. And no other tool steel is as stable. Proof: after 12 years, a typical Graph-Mo steel master plug gage changed less than 10 millionths of an inch in dimension!

More facts about Graph-Mo Hollow-Bar? Write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

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SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

As I was saying...

IT IS difficult for me to become accustomed to a delay of 45 days when I prepare once a month this brief message to you. But it seems that the printer can work only so fast, and here on the first of April I am writing this message which will not reach you until the 15th of May. I could cut the time interval to five days if I sent you a letter by first-class mail, but that would immediately involve $750 for postage, 25,000 envelopes at $6, and 25,000 sheets of good stationery (you rate only the best). That total would scare the life out of me, shock the Board of Trustees, and I don't doubt even you would rate the information worth much less than the cost.

So I guess I'll have to get used to this 45-day period and be appreciative of this two-thirds page for my message, because up to now the bookkeeping department has failed to bill me for the space.

After this laborious and extended comment I am going to get right down to business.

Western Metal Exposition—Closed in a blaze of glory . . . over 53,000 visitors . . . approximately 25,000 registered . . . over 400 exhibitors . . . not a square inch of available space remained . . . beautiful decorations—aluminum etchings, royal red carpet . . . full list of metalworking equipment, materials and processes . . . exhibitors all reported fine business, high-class attendance . . . visitors in buying mood . . . eastern exhibitors impressed with vitality of western manufacturing.

Western Metal Congress—All meeting rooms packed . . . technical sessions by A.S.M., A.W.S., S.N.T., I.H.E.A., and the Los Angeles chapter of A.F.S. . . . outstanding group of speakers . . . Young Engineers' Day on Friday—1700 students from local junior colleges and universities. The Ninth Western Metal Congress and Exposition will be hard to beat.

The Tenth Western Metal Congress and Exposition will be held in Los Angeles, March 25 through 29, 1957.

Just space to tell you of two important acquisitions to headquarters staff. Dr. Anton deSales Brasunas, a graduate of Ohio State and M.I.T., at present associate professor of metallurgy at the University of Tennessee, has been appointed director of A.S.M. educational activities and head of the Metals Engineering Institute, which is now proceeding full steam ahead in the preparation of the A.S.M. correspondence courses (for full details see "A.S.M. of Tomorrow," December 1954 *Metal Progress*). Tone is finishing his teaching year at Tennessee, but will devote full time and move to Cleveland at the close of this semester.

John Tyrrell, also a graduate of M.I.T., for the last four years a representative of *Metal Progress* in the New York territory, has become associate editor in Cleveland. For more details see p. 122.

The last of May I will be sailing with the A.S.M., 200 strong, for the Joint Metallurgical Societies meeting in Europe, with a week in London, and a week each in Germany and France. At the conclusion of the meeting in Paris, the members will scatter to Italy, Austria, and some to Spain with me. I'll give you a bird's-eye view of the Folies Bergère.

Cordially yours,

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

Bill

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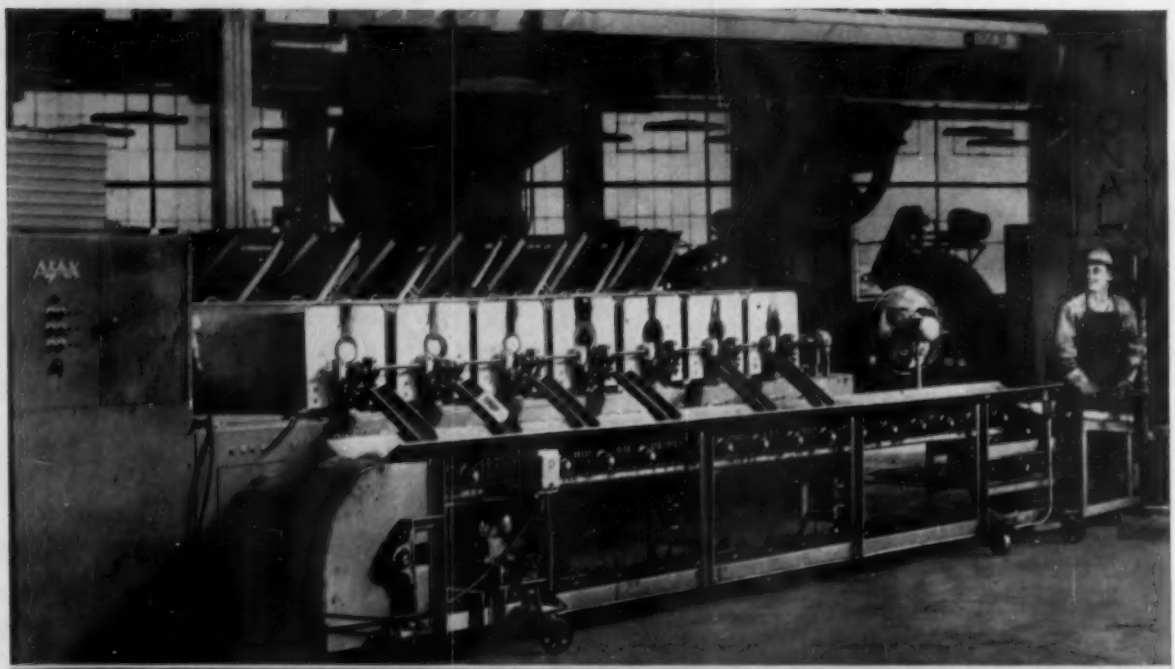

want to mechanize forging?

This large forge shop could show you now. Turning out auto and tractor gears along with hundreds of other parts large and small, it relies upon Ajax induction heating for faster, more efficient production . . . lower material cost . . . greatly reduced manpower . . . and an impressively low reject average.

A complete battery of over a hundred Ajax-Northrup heaters can be put into service here for heating bars of various lengths and weights and in sizes from one inch rounds to four inch squares, each scheduled for automatic or even patterned heating at just the desired rate for the forging operation. Rapid induction heating makes scale formation almost nonexistent; forging dies last much longer.

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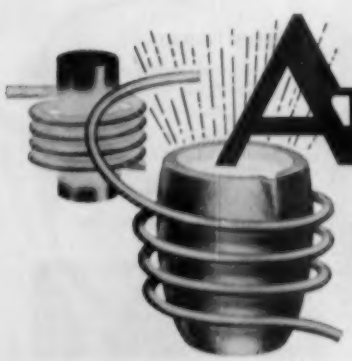
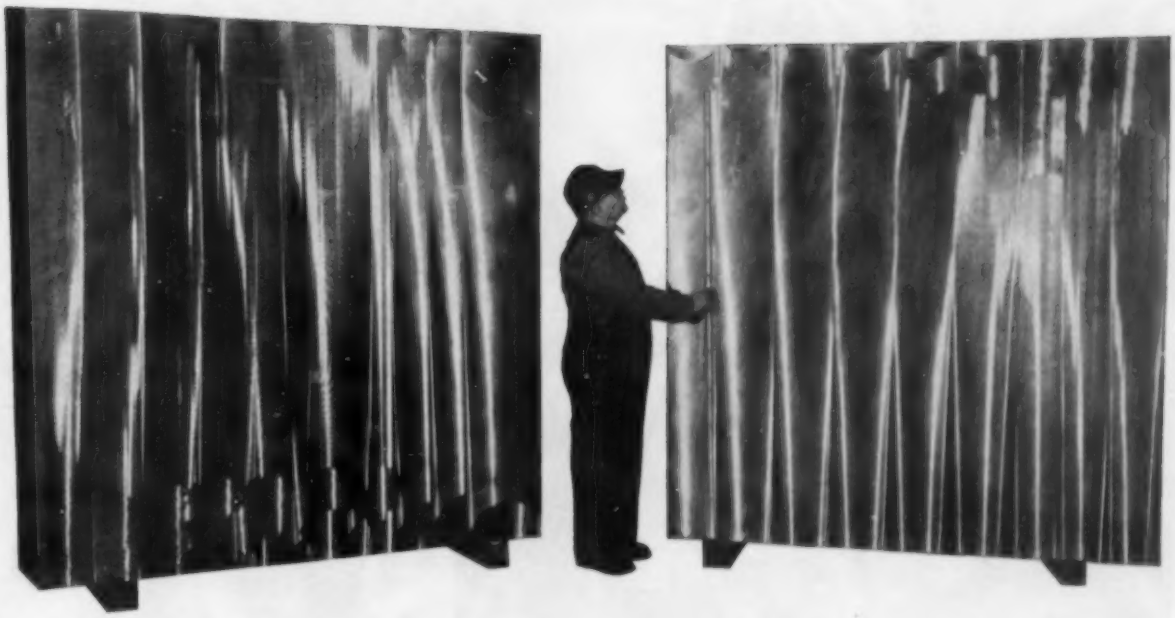
Associated Companies: Ajax Electric Company—Ajax Electric Furnace Co.—Ajax Engineering Corp.



AJAX NORTHRUP *SINCE 1916*

INDUCTION HEATING-MELTING



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Write for this free catalog telling all about Finkl die blocks and forgings, the types of steel, the proper selection for the job, how to make dies last longer, and many other helpful facts. Please send request on your company's letterhead.

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Eastern Warehouse **EAST CAMBRIDGE 41:** Industrial Steels, Inc., 250 Bent Street, ELliot 4-7650

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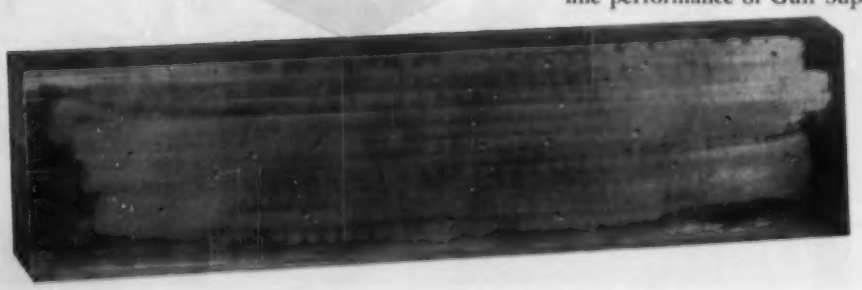

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13. Am I proud of the appearance of my testing equipment?

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engineering digest OF NEW PRODUCTS

Atmosphere Furnace

Cooley Electric Mfg. Corp. has announced a new general purpose furnace with a newly developed protective atmosphere for general hardening of tool steels, carburizing and other heat treating operations. The atmosphere system consists of a cracking unit to which is fed by means of a variable speed pump, a mixture

of alcohol and water proportioned according to the type of treatment desired. This mixture is cracked into gas of a controlled analysis to maintain the correct carbon potential for equilibrium with the steel being treated. The chamber dimensions are 8 x 6 x 14 in. and the power rating is 4.8 kw. at 230 v.

For further information circle No. 1188 on literature request card, p. 32-B.

Barrel Finishing

A standard-model barrel finishing machine with many features of the deluxe models has been announced by Minnesota Mining and Mfg. Co. The machine has all moving parts enclosed. Safety features include a pivot-mounted gate which closes when the machine is in operation and a magnetic brake. All lubrication points are readily accessible, since the motor, speed reducer, speed changer and brake are mounted in a single unit at the rear. The model is available in three power ranges, with a

1½ hp. motor for ordinary requirements, a 2 hp. motor for heavy duty work or a 3 hp. motor for extra heavy finishing jobs.

For further information circle No. 1189 on literature request card, p. 32-B.

Vacuum Pumps

F. J. Stokes Machine Co. has announced two new lines of high vacuum pumps—a series of oil diffusion pumps and one of booster pumps. Both have a "Ring-Jet" feature which increases the pumping capacity by more than 50%. The new "Ring-Jet" design replaces the conventional jet cone with a ring of jets, permitting the cross-section area of the air-flow path to be substantially increased without increasing the distance from the beginning of each jet stream to the nearest condensing surface. Diffusion pumps are available in 4, 6, 10, 14 and 16-in. sizes and booster pumps in 4, 6, 10, and 16 in. sizes.

For further information circle No. 1190 on literature request card, p. 32-B.

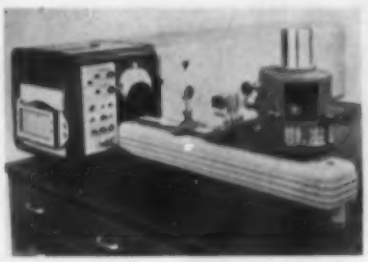
Tin Plate

Heavy gage electrolytically-coated tin plate has been announced by Jones & Laughlin Steel Corp. Where corrosion is not too great a factor, the new tin plate is being used as a replacement for long ternes, aluminum, zinc coated sheets and other metals of higher cost. The heavy gage tin plate comes in three coating weights: No. 25, which has a tin coating of 0.009 oz. of tin per square foot; No. 50, at 0.018 oz. per sq. ft.; and No. 75 at 0.027 oz. per sq. ft.

For further information circle No. 1191 on literature request card, p. 32-B.

Spectrograph

A new spectrograph which uses two gratings was announced by the Bausch & Lomb Optical Co. The instrument will photograph complex spectra found in new metals and materials such as high temperature al-

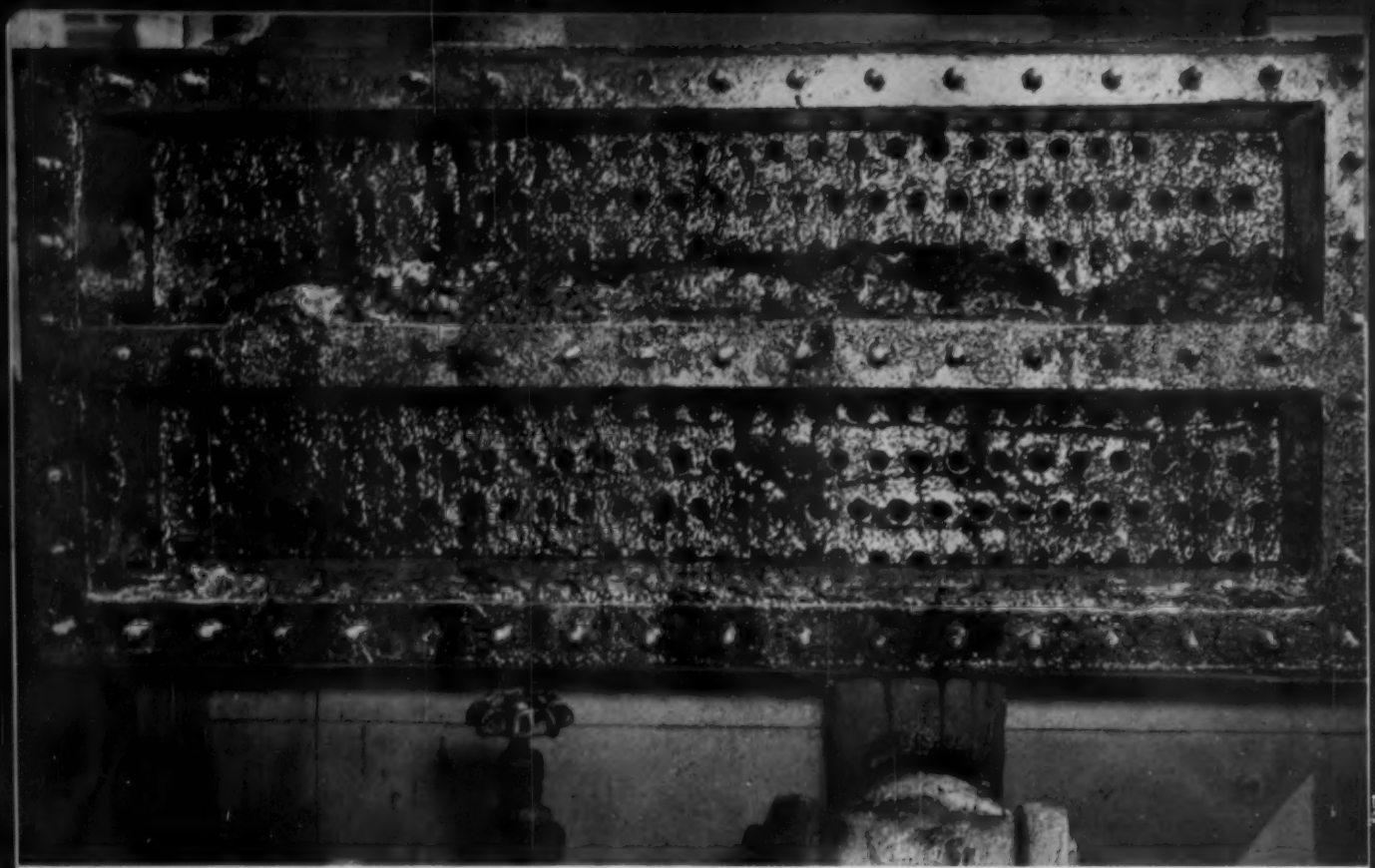


loys, uranium products and rare earths. The use of two gratings in the new spectrograph provides two different spectral ranges in a single exposure on a single plate or on two different plates. One grating operates in a range of 1850 to 24000Å, the second grating in a range of 1850 to 12000Å. The new step-variable system provides a slit which can be opened quickly for thorough cleaning but which is returned automatically to any one of several precise widths with an accuracy of half a micron. Any one of several widths can be placed in operation with a simple dial selection knob.

For further information circle No. 1192 on literature request card, p. 32-B.

Small Chilling Unit

The addition of a 2 cu-ft. low temperature freezer to their standard line has been announced by Cincinnati Sub-Zero Products. First built as a special unit for testing laboratories, it was found to be suitable to the chilling requirements of industrial users and is now being furnished as a standard model. It has a clear opening of 21⅛ x 10⅛ in. The chilling chamber size is 24 x 12 x 12 in. At −20° F. with convection fluid the machine has a capacity of 300 Btu. per hour. Standard accessories include a 500



If you use an ordinary quenching oil that forms sludge deposits, here's what can happen to your oil cooler.

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Sludge lowers operating efficiency, ups maintenance costs, cuts output. Sun Quenching Oil Light, when used at normal temperatures, keeps coolers clean, because it has a natural detergent action that prevents the formation of sludge deposits and aids in removing any deposits that have accumulated. And this oil thins out when heated—reduces drag-out, brings operating costs down. The booklet "Sun Quenching Oils" tells the story of Sun's money-saving quenching oils. Call a Sun office or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-5.

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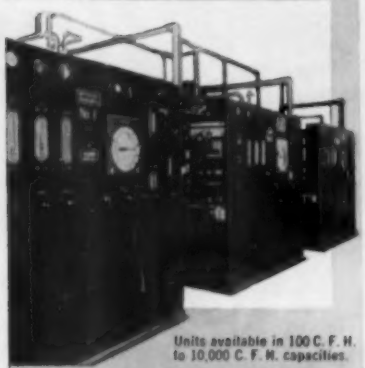

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watt heater to convert the machine for high and low temperature testing, a fan for rapid cooling or heating, observation windows in top or front, interior lights, entrance holes, electrical connections within the chamber and instrumentation as required.

For further information circle No. 1193 on literature request card, p. 32-B.

Filters

Full flow filters offering flow rates up to 900 gal. per min. have been announced by the Filtration Div., Houdaille-Hershey of Indiana. New units can be used for filtering a wide variety of liquids including engine lubrication and fuel oils, metal-working oils and coolants, and parts washing solutions. The new filters are designed for in-line installation and combine compactness with exceptionally high flow capacity to insure continuous filtration of entire oil or coolant supply. Nine different sizes are available using 1 to 36 cartridges. Extra-large dirt holding capacity is obtained by a resin-impregnated pleated paper cartridge having 44 sq. ft. of filtering surface. Filter element in cartridge is inert and will not remove additives found in many oils. It will not soften or disintegrate when used on coolants or other liquids having a water base.

For further information circle No. 1194 on literature request card, p. 32-B.

Contour Projector

A portable bench-type contour projector which is equally adaptable for either horizontal or vertical projection gaging has been announced by Eastman Kodak Co. The projector is designed for checking of small parts which may be inspected by staging in simple holding fixtures for horizontal projection or placing on an easily-

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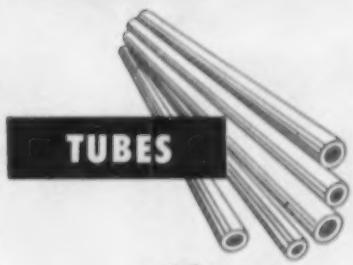

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mounted glass stage, with the machine turned on end, for vertical projection. Six magnifications (10 to 100 ×) are provided, with all lenses quickly interchangeable and positively seated for rated magnification.

For further information circle No. 1195 on literature request card, p. 32-B.

Control Instrument

A new control initiating instrument has been announced by General Electric's Instrument Dept. It is an automatic, all-electrical device for initiating action when a predetermined value is reached. The system picks up the signal from the instrument pointer which eliminates mechanical contacts. Typical applications are: to sound an alarm when the controlled temperature reaches a critical value, to initiate control to contain cycles per second within a specified range, to shut down equipment at a maximum vibration point and to shut down machinery drawing more than normal power.

For further information circle No. 1196 on literature request card, p. 32-B.

Titanium Bolt

Fabrication of light-weight titanium bolts has been announced by Standard Pressed Steel Co. While weighing only 57% as much as its steel counterpart, the new fastener makes possible the part-for-part substitution of titanium for steel bolts in critical tension applications on aircraft. Weight saving without loss of strength can reach 1000 lb. in a single airplane. Bolts tested have shown that, pound for pound, they can take a maximum dynamic load more than twice that of comparable steel bolts without failing through fatigue.

For further information circle No. 1197 on literature request card, p. 32-B.

Key Driver

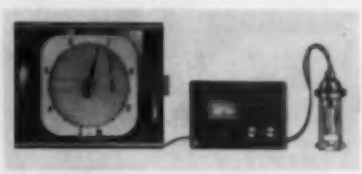
Erie Foundry Co. has announced its new key driver for driving die and sow block keys in forging hammers. The key driver replaces the method of driving keys by using a battering ram suspended from an overhead crane on the building structure.

The new key driver, which operates pneumatically using plant air, delivers an accurate blow with the controlled force of an 800 lb. steam hammer if desired. It is a portable modified horizontal hammer and is usually handled by a fork-lift truck. Average key driving time, including carrying the key driver to and from the hammer, is cut to 20 min. while the battering-ram method consumed 3½ hr. a change. Only two men are required and accidents have been reduced.

For further information circle No. 1198 on literature request card, p. 32-B.

pH Instrumentation

Complete systems for pH recording and control have just been announced by the Bristol Co. These pH instru-



ment systems include an electronic Dynamaster potentiometer recorder or controller, a Beckman Model W amplifier, electrode assemblies in either flow or immersion types and a

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A self-contained variable d.c. power supply for electrolytic etching of prepared metallographic specimens.

This neat compact unit is always ready to operate eliminating time consuming hook ups and delays due to battery failure.

All controls are advantageously located for fingertip adjustment. Twin type voltmeter and ammeter are positioned for ready and easy observation.

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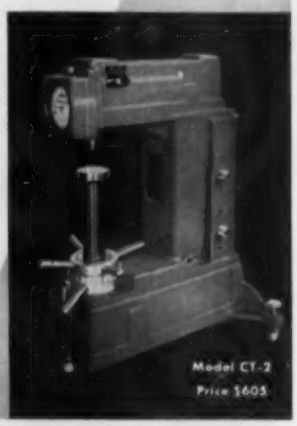

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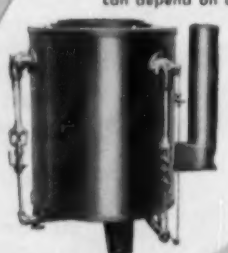

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variety of final control elements for the addition of gaseous, liquid, solid or slurried reagents.

For further information circle No. 1199 on literature request card, p. 32-B.

Shell Molding

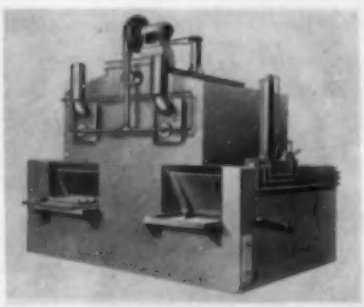
C & S Products Co. has announced a new machine for making both shell molds and shell cores, separately or simultaneously. The machine blows

resin and coated sands into heated core boxes to produce shell cores or into heated patterns or die cavities to produce molds. Curing commences immediately. It requires 24 sq. ft. of floor space and is a two-station operation. The standard machine will accommodate patterns up to 15 x 20 in. and up to 36 in. in height.

For further information circle No. 1200 on literature request card, p. 32-B.

Heat Treat Furnace

A new small batch furnace for controlled atmosphere heat treating has been announced by Holcroft and Co. The furnace is designed for heat treating parts for small plants and for



large ones which have limited or varied production problems. Such typical cycles as carburizing, carbonitriding, bright hardening, normaling, annealing, tempering and non-ferrous heat treating can be run. The furnace has the capacity to heat 500 lb. gross per hour to 1500° F. It can be operated at temperatures ranging from 400 to 1800° F. The furnace requires less than 63 sq. ft. of floor space. No pits are needed.

For further information circle No. 1201 on literature request card, p. 32-B.

Universal Tester

A new table model universal testing instrument has been announced by Instron Engineering Corp. This instrument records stress-strain curves under tension or compression. It is adaptable for quality and production control as well as for research requirements. Full scale load ranges from 2 g. to 200 lb. are available through the choice of three load cells. A space of 3 in. is provided around the crosshead assembly to permit the use of special conditioning chambers, without modification of the unit.

For further information circle No. 1202 on literature request card, p. 32-B.

Spectrochemical Unit

Applied Research Laboratories has announced the Quantograph for spectrochemistry. This new instrument combines the features of a spectrograph, a monochromator and the

Quantometer. The machine will accomplish photography of spectra for complete analysis, polychromatic spectrometry for direct-reading quantitative analyses and monochromatic spectrometry for qualitative and quantitative analyses.

For further information circle No. 1203 on literature request card, p. 32-B.

Emulsion Cleaner

Kelite Products has announced a dust-free composition—freely soluble in water—for the removal of protective mill oil from steel. Kelite MD-1 is used as a tank immersion cleaner at 160 to 180° F. The cycle employed is 0.5 to 3.0 min. depending upon the amount and tenacity of the soil present. MD-1 is strongly buffered and exhibits a fairly constant pH over a wide range of concentration. In the recommended concentration it exhibits

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NEW! PYRO Micro-optical Pyrometer

Sufficiently portable to be used for general plant operations, the new Pyro Micro-Optical Pyrometer has been developed to meet the demand not only for higher degrees of accuracy, but also greater versatility in measurement of temperatures over 760° C. (1300° F).

It measures targets less than .001" in diameter, and, by means of supplementary lenses, can be adjusted for focal distances from five inches to infinity. Mountings on table-top and floor-type tripods are available, and vernier worm gears permit extremely fine vertical and horizontal adjustments of the telescope. Wide-scale, direct-reading meter makes for extremely accurate reproduction of temperatures. Ask for free catalog No. 95.

PYRO Surface Pyrometer

Designed to meet all plant and laboratory surface and sub-surface temperature measurements with selection of thermocouples and extension arms. The improved Pyro is quick acting, accurate, light-weight and rugged. It features large 4½" direct reading scale, automatic cold end junction compensator and shielded steel housing—all combined to offer highest precision, accuracy and dependability. Available in five standard ranges from 0-300° to 0-1200° F.

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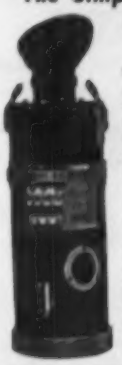
The Simplified PYRO Optical Pyrometer



Gives accurate temperatures at a glance. Any operator can quickly determine temperatures of minute spots, fast moving objects and smallest streams. Completely self-contained, no correction charts or accessories needed. Weighs only 3½ lbs. Direct reading with special types for true pouring temperatures of molten ferrous metals. Five temperature ranges from 1400°F to 7500°F. Ask for free Catalog No. 85.

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QUENCHING SPEED TO FIT YOUR NEED

good cleaning ability for intervals of one month or more.

For further information circle No. 1204 on literature request card, p. 32-B.

Calorimeter

A calorimeter that records directly and continuously in terms of the heat flow factor instead of Btu. has been announced by Cosa Corp. The new regulator permits a flow of gas which is inversely proportional to the square root of the specific gravity, so that the heat available at the burner is proportional to the heat flow factor. Use of the new recorder eliminates the need for spot checking specific gravity and Btu. value and using a formula to obtain the information. When the new instrument is combined with pneumatic control, it can adjust the mixing of two gases and keep the heat flow factor constant. It can be fitted with electric alarm contacts to give visible or audible warning when the heat flow factor goes over pre-set limits.

For further information circle No. 1205 on literature request card, p. 32-B.

Spectrographic Standards

A new set of eight low-alloy steel spectrographic standards has been announced by Jarrell-Ash. They are issued by the British Bureau of Analyzed Samples, Ltd. Standardization was accomplished through cooperative analysis by twelve analytical chemists representing their respective steel firms. The standards are in the form of rods ½ in. in diameter by 6 in. long. Individual certificates accompany the standards and the results of the twelve analyses are tabulated and averaged and their analytical techniques are outlined.

For further information circle No. 1206 on literature request card, p. 32-B.

Die Casting Machine

A new higher speed design of the Model BH-30 die casting machine has been announced by the Kux Machine Co. This machine, a plunger gooseneck type for the production of zinc, lead or tin die castings, has been increased in over-all weight to 24,000

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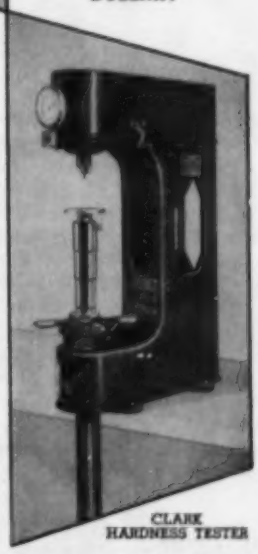

CLARK HARDNESS TESTER

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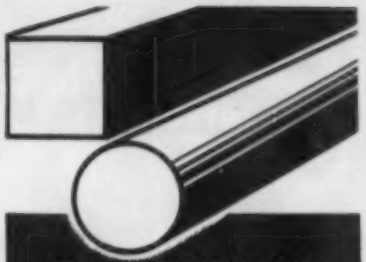

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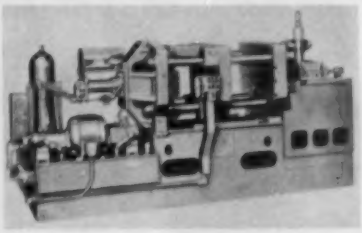
3-M-1

MERRILL BROTHERS
56-31 ARNOLD AVENUE
MASPETH, N. Y.

lb. through use of heavy 6 in. thick solid steel die plates, 4 in. diameter tie bars and a channel steel base, extending the length of the machine.



Die clamping pressure capacity is rated at 400 tons. Very large dies can be handled, and deep draw castings can be produced.

For further information circle No. 1207 on literature request card, p. 32-B.

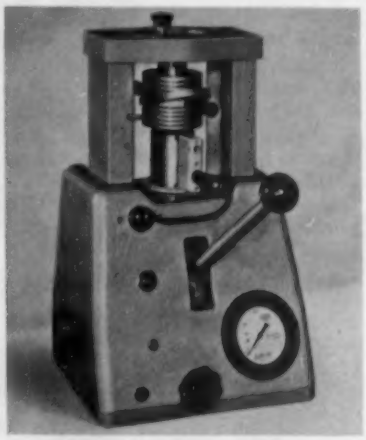
Welders

Air Reduction has announced a new low-cost high-efficiency a.c. arc welding machine, for use wherever a general utility welder is needed. Two models are available—one with and one without power factor correction. The right heat setting can be selected by simply turning the current control crank on top of the case for exact increments from 20 to 180 amp. The open circuit voltage is adequate for successful operation with standard electrodes. The machines are ruggedly constructed and come equipped with a primary cable with three-prong plug and receptacle, and four casters for easy mobility.

For further information circle No. 1208 on literature request card, p. 32-B.

Mounting Press

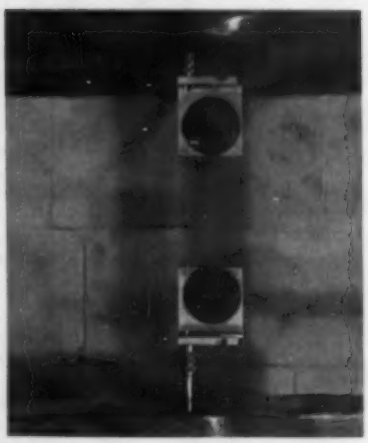
Buehler, Ltd., has announced a new specimen mounting press for the preparation of metallurgical samples. Design features include automatic temperature control, center ejection of the completed specimen, and the possibility of using both 1 and 1¼ in. specimen molds with the same heater and cooler.



For further information circle No. 1209 on literature request card, p. 32-B.

Wire Testing

New snubber type grips for tensile strength tests of wire up to 0.06 in. dia. have been announced by Baldwin-Lima-Hamilton Corp. These grips were designed to minimize or prevent breaks at the grips and thus permit breaks to occur within the free length of wire specimens. Grips consist of 3-in. dia. hardened steel drums secured to aluminum brackets. Ends of wire wound around the drums one or more times are held by screw clamps on the brackets. Brackets are supported by spherically seated tension rods held in matching wedge grip slot adapters in the crossheads of the testing machine. Centerlines of the free length of wire in tension and of the tension rods coincide, as shown.



For further information circle No. 1210 on literature request card, p. 32-B.

How to use
New USS "T-1" Steel
to reduce welding costs

New USS "T-1" Steel is three times as strong as ordinary mild steel . . . has a yield strength of 90,000 psi.

Yet, despite its very high strength, this new alloy steel is *easy to weld*. It requires neither pre- nor post-heating when you weld or flame cut it. You can use its unique combination of properties to reduce fabricating costs and speed assembly in pressure vessels, construction machinery, mining equipment, bridges, towers, and pipe.

USE "T-1" TO REDUCE THICKNESS. You can take advantage of the exceptionally high yield strength of "T-1" Steel to reduce the size and weight of heavily stressed parts. Weldments on thinner sections take less time . . . and less welding rod.

FABRICATE "T-1" IN THE FIELD. You can weld "T-1" Steel *anywhere*. Since no pre- or post-heating is needed, you don't have to confine fabrication to locations where heat treating facilities are available. You can assemble heavy-duty equipment in the field, and you can repair it in the field—at great savings.

WHAT ABOUT JOINT EFFICIENCY? Weldments in "T-1" Steel develop the full yield strength of the steel — 90,000 psi.—when made with AWS E12015 low hydrogen coated electrodes *without* pre- or post-heating. As a result, weight reducing designs based on the greater strength of "T-1" Steel are completely safe and reliable.

Send the coupon for complete facts about this amazing new alloy steel.

United States Steel, Room 4716
525 William Penn Place, Pittsburgh 30, Pa.

☐ Please send me your booklet "United States Steel presents T-1" which contains the full story of "T-1" steel.

☐ Have your representative get in touch with me.

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UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. • UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS "T1" CONSTRUCTIONAL ALLOY STEEL

SEE THE UNITED STATES STEEL HOUR. It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

USS

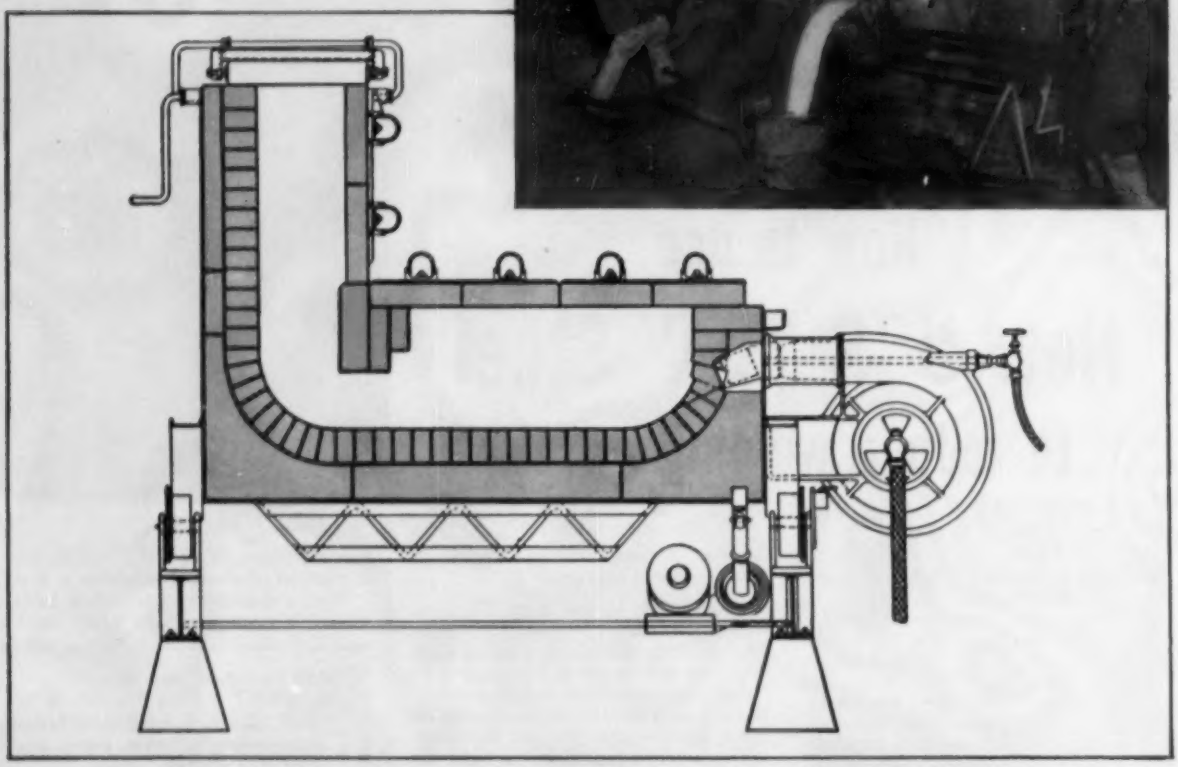
5-477

UNITED STATES STEEL

Another Norton Rx *on the job!*

CRYSTOLON* baffle plates contribute to the high melting efficiency of Reda reverberatory furnaces

Reladling ductile iron from a Reda reverberatory furnace for ferrosilicon addition. These furnaces are designed for fast, low cost melting of both ferrous and non-ferrous alloys.



Cross-section of a reverberatory furnace manufactured by the Reda Pump Co. of Bartlesville, Okla. Charge is through the stack and the metal is heated by direct impingement of the flame passing over the metal bath and by reflected heat from roof and side walls. Melting takes place at base of stack, where CRYSTOLON baffle plates (shown in color) are the Norton Rx — an expertly engineered refractory prescription — for this critical spot.

CRYSTOLON refractory material is *engineered* to combine great physical strength with exceptional resistance to thermal shock, slag penetration and chemical attack. It will withstand temperatures up to 3050°F, and has up to 15 times the resistance of ordinary fire clay to erosion and corrosion.

That is why CRYSTOLON baffle plates were *prescribed* for Reda furnaces — adding another to the long list of highly successful Norton Rx's for the metal melting field.

Whatever your own furnace operations may be, there is a Norton Rx that will help you to save time, labor and money. For information about Norton CRYSTOLON*, ALUNDUM*, MAGNORITE* and FUSED STABILIZED ZIRCONIA refractories — standard or special shapes or cements — see your Norton representative. Or write to NORTON COMPANY, Refractories Division, 324 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto 5, Ontario.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

1229. Abrasive
Bulletin on aluminum oxide barrel finishing compound for tumbling and precision finishing. *Simonds Abrasive Co.*

1230. Abrasive Cleaning
Catalog 54-W on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass, Brush Div.*

1231. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

1232. Air-Gas Mixer
Bulletin L-700 gives engineering and application data on air-gas proportional mixer. *Eclipse Fuel Eng'g*

1233. Alloy Cast Iron
64-page bulletin A-71 on engineering properties and applications of Ni-Resist. Corrosion data comparing with gray cast iron. *International Nickel Co.*

1234. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD, and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

1235. Alloy Selection
Chart to select alloy for given corrosive problem. 350 corrosives included. *Cooper Alloy Foundry*

1236. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

1237. Alloy Steel
207-page book gives more than 50 complete case histories of alloy steel usage. *Climax Molybdenum*

1238. Aluminum Alloy
Bulletin 103 on high strength aluminum alloy which ages at room temperature. *Federated Metals Div.*

1239. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1240. Aluminum Heat Treating
8-page Bulletin 5012 on solution heat treating, annealing, stabilizing and aging of aluminum. *General Electric*

1241. Aluminum Processing
Article on gas fired furnaces for heat processing of aluminum in Heat Treat Review, Vol. 5, No. 3. *Surface Combustion*

1242. Aluminum Welding
Data on chemical composition of aluminum welding rods and electrodes. *Arcos Corp.*

1243. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

1244. Annealing Brass
8-page Bulletin S-1049 on high-speed annealing of brass strip for improved ductility. *Selas Corp.*

1245. Atmosphere Furnace
12-page bulletin on electric furnaces with atmosphere control for hardening high speed steel. *Sentry*

1246. Atmosphere Furnaces
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

1247. Atmosphere Generator
Bulletin 439 on exothermic atmosphere generators for converting natural gas, manufactured gas, propane or butane. *W. S. Rockwell*

1248. Atmosphere Generator
Bulletin on laboratory size dissociated ammonia generator. *Boder Scientific*

1249. Atmospheres
New 12-page bulletin on use of protective atmospheres to prevent deterioration of metals during various heat treating processes. *General Electric*

1250. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

1251. Austempering
8-page booklet No. 500 on present status of austempering and martempering—development, S-curve theory, reasons for austempering and martempering. *Ajax Electric Co.*

1252. Beryllium Copper
Bulletin 1 on available alloys, conditions, tempers and tables of sizes and properties. *Penn Precision Products*

1253. Beryllium Nickel
4-page leaflet on high-strength, corrosion-resistant beryllium-nickel casting alloys. *Beryllium Corp.*

1254. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

1255. Blast Cleaning
4-page bulletin on nonmetallic, dustless mineral shot for blast cleaning. *Baldwin-Hill Co.*

1256. Blast Cleaning
24-page catalog 1210 on equipment and accessories for blast cleaning and dust control. *Pangborn*

1257. Brass
80-page book on properties and uses of brass forgings, sand castings, rods and machinings. *Mueller Brass*

1258. Brazed Tubing
12-page data book on brazed tubing made from copper coated steel. *Bundy*

1259. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

1260. Brazing Aluminum
12-page bulletin, ADR 45, on how to torch braze aluminum and strength of joints so brazed. *Air Reduction Sales*

1261. Brinell Machine
Data on semi-automatic Brinell testing machine. *Detroit Testing Machine*

1262. Brush Selector
Setting selector at brush diameter, selection may be made in choice of steel, stainless, phosphor bronze, tampico or cord. *Fuller Brush Co.*

1263. Calibrating Machine
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

1264. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

1228. Grinding and Polishing
Coated abrasive polishing and grinding technics are the subject of this 60-page booklet. It is an assemblage of 20 articles on production engineering for coated abrasives and includes such topics as coated abrasives theory and practice, contour polishing and grinding, inside polishing of recesses and small openings, contact wheels, part sizing and deburring, swing frame grinding, abrasive belt lubrication, disc grinding. *Behr-Manning Corp.*

1265. Case Hardening
Bulletin 150 describes standard rated batch furnaces for case hardening. *Surface Combustion*

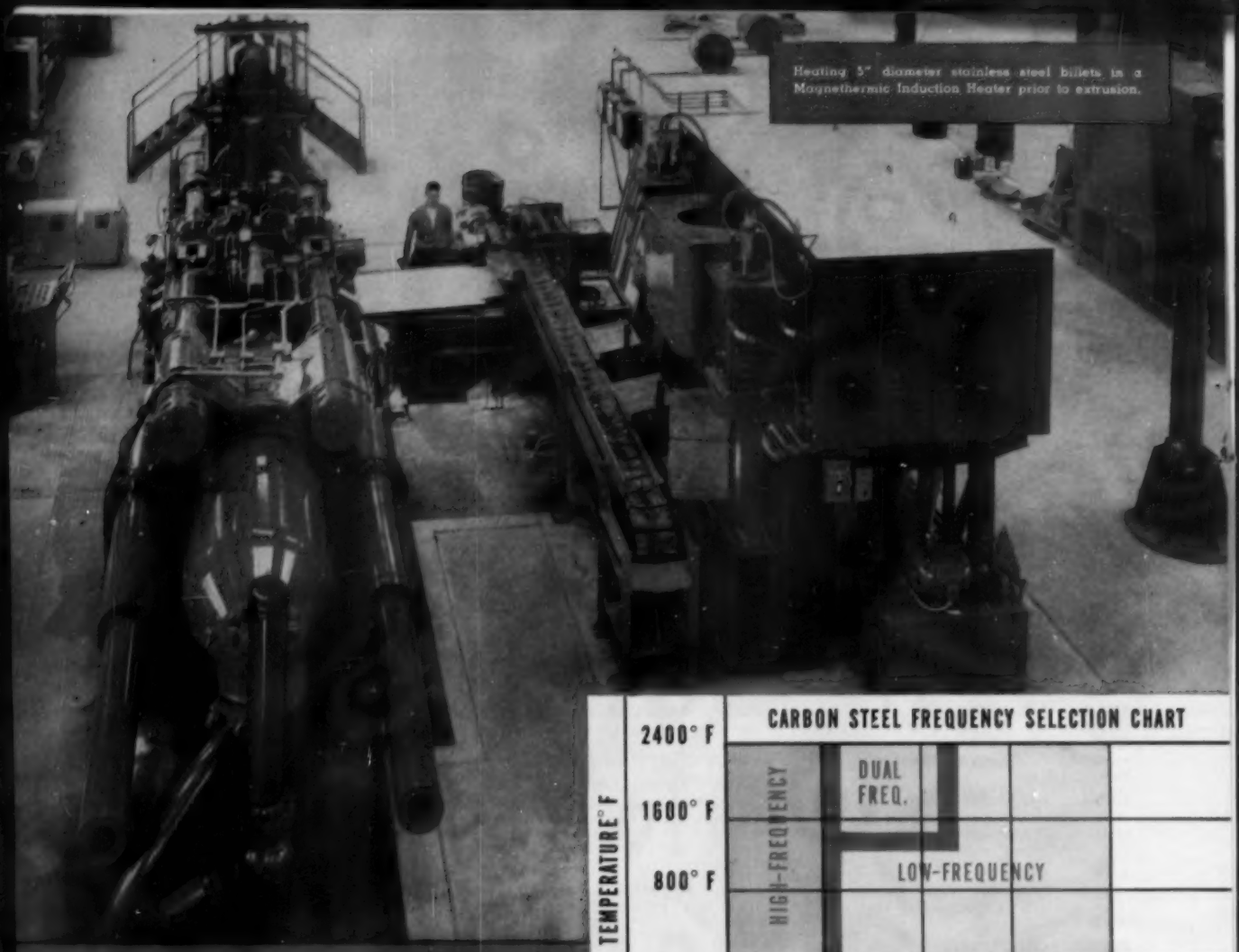
1266. Castings, Bronze
16-page booklet on sand and centrifugal castings. *American Non-Gran Bronze*

1267. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products.*

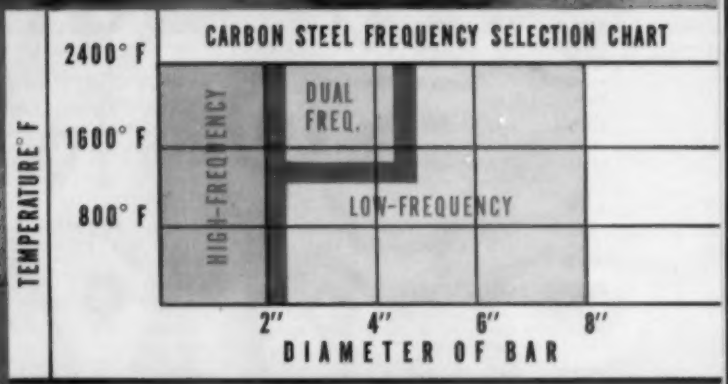
1268. Chromium Cast Iron
48-page book on effects of chromium on properties of cast iron. Data on production and uses. *Electro Metallurgical*

1269. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

1270. Cleaning
Data sheets on acid activators to pro-



Heating 5" diameter stainless steel billets in a Magnethermic Induction Heater prior to extrusion.



FORGE WITH INDUCTION HEATING

AND DO A BETTER JOB

With induction heat, a 5" diameter steel billet reaches forging temperature in less than five minutes. This rapid heating cuts operating costs by minimizing scale loss, maintenance costs, manpower and floor space. The equipment can be fitted into an automatic processing line, making billet pre-heating just one minor step in a forging operation. This is why modern production forging and extrusion plants are buying induction heating equipment.

Regardless of size of work or frequency, Magnethermic builds the equipment to meet your need. This company specializes in Induction Heating equipment, low-frequency or high-frequency, through 10,000 cycles. Write to Magnethermic for bulletin or information about your specific questions.

60 THROUGH 10,000 CYCLES

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mote removal of scale and oxides from steel and iron. *Swift Ind. Chem.*

1271. Cleaning
Bulletin on equipment for cleaning and pickling of shell cases and other ordnance items. *Alvey-Ferguson*

1272. Cleaning
20-page bulletin 214 gives performance on Rotoblast cleaning. *Pangborn*

1273. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25," tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

1274. Cold Finished Bars
Engineering bulletin, "New Economies in the Use of Steel Bars." *LaSalle Steel*

1275. Cold Treatment
Bulletin on sub-Arctic industrial cabinets for metal treating and research and production testing. *Tenney Eng'g.*

1276. Colored Coil
Folder on aluminum, steel or other metallic coil finished in permanent colors. *Southern States Iron Roofing Co.*

1277. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

1278. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1279. Continuous Casting
24-page book, "Better by the Mile," describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

1280. Controlled Atmospheres
Bulletin 753 on generator for atmospheres for hardening, brazing, sintering and annealing carbon steels. *Hevi Duty*

1281. Controllers
20-page bulletin 2102 on application of controls and combustion safeguards to North American combustion equipment. *Minneapolis-Honeywell*

1282. Controllers
48-page bulletin P 1260 on pyrometers, thermometers, control valves for furnaces, ovens, dryers. *Bristol*

1283. Controllers
80-page catalog 8305 on nonindicating electric, electronic and pneumatic controllers for temperature, pressure and humidity. *Minneapolis-Honeywell*

1284. Copper Tubing
24-page booklet on uses and properties of copper water tube, dryseal tube, red brass and copper pipe. *Revere*

1285. Corrosion of Copper
28-page booklet B-36 discusses corrosive attack on copper and copper alloys. Tabulation of their relative corrosion resistance. *American Brass*

1286. Corrosion Resistant Alloy
Data sheet compares corrosion properties of Elgiloy and stainless steel. *Elgin National Watch Co.*

1287. Corrosion Resistant Alloy
20-page booklet on nickel, chromium, molybdenum, iron alloy gives chemical composition, corrosion data, properties and welding characteristics. *Haynes Stellite*

1288. Creep Testing
6-page bulletin diagrams and describes dynamic creep testing machine. *Ivy Co.*

1289. Creep Testing
Bulletin RR-13-54 on new creep testing machine. *Riehle*

1290. Crystal Models
Folder describes unique kit for constructing crystal models. *Harshaw*

1291. Cutting Oil
Folder on sulphurized cutting fluid for a wide range of machining jobs. *Gulf Oil*

1292. Cut-Off Wheels
36-page revised manual on cut off machines and abrasive wheels. *Norton Co.*

1293. Definitions
36-page glossary of over 150 terms on cast iron. *International Nickel*

1294. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1295. Degreasing
New bulletin 953-1 on vapor degreasing, and advantages. Equipment. *Ramco Equipment*

1296. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

1297. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

1298. Dew Point Control
Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipsen*

1299. Die Casting
Bulletin on high-pressure hydraulic die casting machine. Convertible from hot metal to cold chamber machine. *Cleveland Automatic Machine Co.*

1300. Die-Casting Machines
Copies of "Lester Press" describe various features of aluminum die casting machines. *Lester-Phoenix, Inc.*

1301. Die Castings
Set of five design standards for tolerances on die casting of zinc, aluminum, magnesium and copper. *American Die Casting Institute*

1302. Dilatometer
Catalog Micro 8161 on equipment for thermal analysis of metals, ceramics. *Leitz*

1303. Electric Arc Furnace
Carbon and Graphite News contains an article on the electric arc furnace, an appraisal for management. *National Carbon*

1304. Electric Furnace
Bulletin on box-type, pre-heat and hardening furnace with automatic atmosphere contamination control. *Pacific Scientific*

1305. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

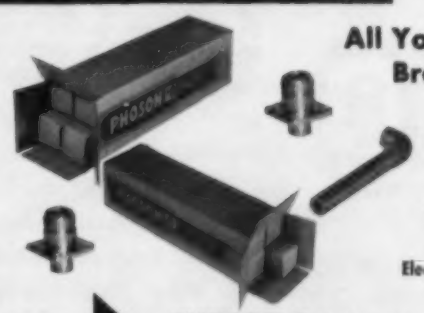
1306. Electroplating
New bulletin on electroplating lists key characteristics of 16 processes. *Hanson-Van Winkle-Munning*

1307. Fatigue of Magnesium
18-page paper, "Plastic Flow and Work Hardening Phenomena in Magnesium Alloys During Fixed-Deflection Fatigue Tests". *Dow Chemical*

PHOSON-0 PHOSON-6

These Two *United* Alloys ...for

All Your Copper and Brass Joining!



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Stampings
Screw Machine Parts
Electrical Connections
etc.

PHOSON-0 (No Silver!)
Industry's most popular alloy choice for brazing closely fitted copper and brass joints where exceptionally low temperature is not an important consideration.

Highly Efficient! Most Economical!
Use Phoson-O for brazing joints of consistently uniform clearances — quickly, safely, surely!

PHOSON-6 (6% Silver)
For really low temperature brazing and complete control of alloy flow . . . where maximum ductility and varying joint tolerances are key factors.

PHOSON-O (No Silver!) PHOSON-6 (6% Silver)
These Two Alloys For All Your Copper and Brass Joining!
Two Good Reasons Why PHOSON BRAZING ALLOYS Are Busier Than Any Brazing Alloys In The Country!

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Wherever Metals Are Joined, Keep Them—
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New Wheelco Model 402 Capacitrol

Typical recorder chart, above, illustrates results you can expect with Wheelco's new Model 402 Capacitrol — "anticipatory" time-proportioning controller for applications requiring fixed compensation for thermal inertia.

. . . totally new and accurate time-proportioning controller

If you want to minimize under- and over-shooting of temperatures in furnaces, ovens, and kilns . . . get more uniform heat distribution . . . or control rate of fuel flow . . . here's the newest and most advanced instrument for the job! For, "anticipatory" action of the "Model 402" is produced directly within the packaged *electronic* control unit. There's no disturbance to, or off-setting of the measuring circuit — indicator always gives you the correct temperature value. Proportioning band is adjustable to a maximum equivalent of 1% of scale. Total cycle time is adjustable from 5 seconds to 45 seconds.

NEED MORE INFORMATION?

Describes and illustrates new design features . . . new control forms . . . and new cost-saving flexibility of Wheelco's new 400 Series Capacitrols. Write for your copy of Bulletin F-6314-1 *today*.

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Industrial Instruments • Automatic Controls • Air Distribution Products • Aircraft Controls • Small Motors Overdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

1308. Ferro-Alloys and Metals
104-page book gives data on more than 250 different alloys and metals produced by the company. *Electro Metallurgical*

1309. Filler Metal
New colored chart gives complete line of filler metals for welding, metal each is suited to, forms available and methods with which it is used. *Arcos Corp.*

1310. Finishes
Experiences with various finishes for different products described in Glidden Industrial Review, Vol. 5, No. 1. *Glidden Co.*

1311. Finishing
52-page book "Advanced Speed Finishing" describes equipment for deburring and finishing. *Almco Div.*

1312. Flaw Detection
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

1313. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g.*

1314. Forging Hammer
New 20-page catalog on design features and uses of electro-pneumatic hammer. *Lobdell United Division*

1315. Forging Lubricants
New Bulletin 426-W1 on forging lubricants of molybdenum disulfide. *Acheson Colloids*

1316. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

1317. Forming
86-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

1318. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1319. Furnace Charging
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

1320. Furnace Controls
Catalog 53-1 on furnace and oven controls including temperature controllers, recorders and indicators and safety control equipment. *Minneapolis-Honeywell*

1321. Furnace Controls
22-page booklet on instruments and controls for heat treating furnaces. *Hays Corp.*

1322. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

1323. Furnace Fixtures
Bulletin 111 on cast Ni-Cr fixtures for gas carburizing. *Fahralloy*

1324. Furnace Pressure Control
Bulletin 7404 on indicating furnace pressure controller and its uses. *Minneapolis-Honeywell Regulator Co.*

1325. Furnaces
Series of bulletins on controlled atmosphere, carburizing, nitriding, hardening furnaces. *American Gas Furnace*

1326. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

1327. Furnaces
Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

1328. Furnaces
8-page bulletin on continuous, car-type, reverberatory, recirculating and other furnaces. *Demsey Industrial Furnace*

1329. Furnaces
6-page folder on gas-fired, oil-fired and electric furnaces. Typical installations. *Electric Furnace*

1330. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric Furnace*

1331. Furnaces
Data on electric furnaces of top or side loading types. *Lucifer Furnaces*

1332. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace quench tank and high temperature furnace. *Waltz Furnace*

1333. Furnaces, Heat Treating
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

1334. Gas-Oil Burner
Bulletin on closed flame gas-oil burners gives operation, capacities, dimensions. *Eclipse Fuel Engineering*

1335. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

1336. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

1337. Handling Devices
Pamphlets on clamps for lifting and handling. Their application to various industries. *Merrill Bros.*

1338. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

1339. Hardness Tester
20-page bulletin on use of portable hardness testers and accessories. *Ames Precision Machine*

1340. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1341. Hardness Tester
New bulletin on Wolpert-Gries Micro-Reflex hardness tester for loads from 10 to 3000 g. *Gries Industries, Inc.*

1342. Hardness Tester
New 4-page folder on portable Brinell hardness tester which can be used in any position. Details of machine and its operation. *Andrew King*

1343. Hardness Tester
13-page booklet on microhardness tester with optional Vickers or Knoop diamond. *Geo. Scherr*

1344. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

1345. Hardness Testers
Catalog of testers for normal hardness, superficial testing, accessory and special testing and micro and macro hardness testing. *Wilson Mechanical Instrument*

1346. Heat Resistant Alloy
10-page article on how to get best service out of standard grades of heat resisting alloys by proper selection. *Rolled Alloys*

1347. Heat Resistant Alloy
6-page bulletin on high-heat resistant muffles and retorts. *Electro-Alloys*

1348. Heat Treating
16-page booklet on cost accounting for heat treating. *Metal Treating Institute*

1349. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

1350. Heat Treating Baskets
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

1351. Heat Treating Fixtures
24-page catalog B-8 on muffles, retorts, baskets, other fixtures for heat treating in gas or salt baths. *Rolock*

1352. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1353. Heat Treating Fixtures
New folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

1354. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances in heat treating furnaces. *Holcroft*

1355. Heating Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

1356. Heliarc Welding
Pocket-sized folder contains current ranges and sizes for electrodes with table on current and number of passes required to weld various metals. *Linde*

1357. High Alloy Castings
New 16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

1358. High-Strength Steel
66-page catalog on Mayari°R steel. Applications which take advantage of its wear and corrosion resistance. *Bethlehem Steel*

1359. High-Strength Steel
26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

1360. High-Strength Steel
48-page book on T-1 steel, its properties and applications. *U.S. Steel*

1361. High-Temperature Belts
24-page bulletin on metal conveyor belts. *Wickwire Spencer*

1362. Indicating Controller
Bulletin F-6314 on Series 400 Capacitrols for indicating and controlling temperatures, voltages, current, speed and similar variables. *Wheelco*

1363. Induction Heaters
New bulletin on low-frequency induction heating describes units for brass, copper, titanium, steel, forgings, light metal extrusion presses. *Magnethermic*

1364. Induction Heating
12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

1365. Induction Heating
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1366. Induction Melting
8-page article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering*

1367. Induction Melting
16-page booklet 14-B on high-frequency converter type furnaces for induction heating and melting of ferrous and nonferrous metals. *Ajax Electrothermic*

1368. Industrial Fans
Catalogs on various kinds of industrial fans — exhaust, multiblade, backward curve, for high temperatures. *Garden City Fan*

1369. Instruments
New data sheets ND46-33 (100) to (104) on indicators, recorders and controllers. *Leeds and Northrup*

1370. Interference Microscope
Bulletin B-602 describes new Zeiss instrument for fast nondestructive examination and photography for wave-length measuring of surface finishes in the order of one millionth of an inch down to 300 Angstroms. *Boder Scientific Co.*

1371. Iridium Radiography
8-page booklet on industrial radiography with iridium 192. Method, advantages, equipment. *Gamma Corp.*

1372. Iron Phosphate Coating
12-page book on how to apply iron phosphate coatings to steel in preparation for painting. *Oakite Products*

1373. Joining
Folder on Koldwelding tool and how it may be used for lap and butt welds. *Utica Drop Forge*

1374. Laboratory Furnaces
Bulletin No. 310 on high temperature electric tube furnaces for laboratories. *Burrell*

1375. Leaded Steel
New 8-page booklet on production of lead treated steels, their advantages and case histories of their use. *Copperweld Steel Co.*

1376. Leaded Steels
Folder on lead-bearing, cold finished bars which machine about 80% faster than B1113. *LaSalle Steel*

1377. Light Metal Heating
New booklet on ovens for heat processing of aluminum, magnesium and titanium. *Michigan Oven*

1378. Light Metal Heating
8-page bulletin on furnaces and equipment for melting and heat treating light metals. *Surface Combustion*

1379. Liquid Level Control
Bulletin 1161 gives basic principles of liquid level measurement, control and transmission. *Minneapolis-Honeywell*

1380. Low-Alloy Steel
60-page book on high-strength low-alloy steel, properties, fabrication and uses. *U.S. Steel*

1381. Low-Temperature Properties
48-page bibliography of characteristics of steels at low temperature covers 1904 to June 1953. *Inco*

1382. Lubricant
Literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

1383. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*

1384. Lubricant
Bulletin 103 on fringe area lubrication with molybdenum disulphide for high bearing pressures and various temperatures. *Alpha Corp.*

1385. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

1386. Magnesium Extrusions
36-page bulletin gives values of moment of inertia, section modulus and radius of gyration of bars, tubing, angles, channels, tees, zees and other sections. *Dow Chemical*

1387. Magnesium Specs
Bulletin DM12n on specifications of government agencies, AMS, SAE, ASTM. *Dow Chemical*

1388. Magnesium Welding
Reprint describes an investigation to evaluate inert-gas-shielded metal-arc welding of magnesium. *Air Reduction*

1389. Malleable Iron
Reprint 51-B on metallurgy, treatment and heat treated properties of malleable iron. *Surface Combustion*

1390. Master Alloys
Bulletin on custom-made alloys for remelt or reprocessing. *Cannon-Muskegon*

1391. Melting Furnaces
8-page Bulletin 560 describes stationary and tilting types of two-chamber melting furnaces. Applications to all types of casting. *Lindberg Engineering*

1392. Metal Cutting
64-page catalog No. 29 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

1393. Metallograph
12-page book on desk-type metallograph. *American Optical*

1394. Metallographic Equipment
12-page catalog E-29 describes bright-field equipment for visual observation and photography. *Bausch & Lomb*

1395. Metallurgical Apparatus
200-page catalog of metallurgical apparatus: cutters, grinders, mounting presses, polishers, metallographs, microscopes, camerns, testing machines, analytical apparatus, spectographs, furnaces, accessories and supplies, and 250 recommended metallurgical books. *Buehler Ltd.*

1396. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

1397. Mill Equipment
Profusely illustrated journal featuring facilities available for production of rolling mills, steel castings and steel rolls. *Continental Foundry & Machine Co.*

1398. Moly-Sulphide Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1399. Molybdenum
20-page brochure on properties of molybdenum, processing and use. Tabulation of products and their characteristics. Flow chart of manufacture. *Sylvania Electric Products*

1400. Nickel Alloys
38-page handbook on wire, rod, strip of Monel, Inconel, nickel and nickel clad copper. *Alloy Metal Wire Co.*

1401. Nitrogen Atmosphere
Bulletin on generator for producing pure nitrogen with a controllable hydrogen content. *Baker & Co.*

1402. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1403. Nonflammable Rust Preventive
Bulletin on rust preventive compound which is water soluble, nontoxic and nonflammable. *Production Specialties*

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Bulletin on method of producing paint bonding and wear-resistant phosphate coatings. *Pennsylvania Salt*

1407. Pickling
80-page book "Efficient Pickling" covers all variables of process. Many charts and tables. *American Chemical Paint*

1408. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1409. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g.*

1410. Plate Fabrication
New 12-page bulletin on experience and facilities for steel and alloy plate fabrication. *Downingtown Iron Works, Inc.*

1411. Powder Metallurgy
Information on sponge iron powder. *Ekstrand & Tholand*

1412. Precious Metals
64-page catalog of products made of precious metals, contact materials, plating solutions. Tables of data on precious metals. *Baker & Co.*

1413. Precision Casting
44-page Catalog 53 covers every stage of the investment casting process. *Alexander Saunders*

1414. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1415. Precision Casting
12-page book on alloy selection and design for precision casting. *Arwood Precision Casting*

1416. Presses
New general catalog and buyers' guide to hydraulic presses and die casting machines. *Lake Erie Engineering Corp.*

1417. Pyrometer Supplies
56-page Users' Manual and Buyers' Guide. Specifications, prices, thermocouple calibration data. *Bristol Co.*

1418. Pyrometers
New bulletin, "Temperature Indications," on basic facts about pyrometry and line of pyrometers. *Illinois Testing Labs.*

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(Continued from p. 30)

1419. Pyrometers
8-page catalog No. 85 on optical pyrometer for plant and laboratory. *Pyrometer Instrument*

1420. Quenching
New catalog on two small self-contained quenching units. *Bell & Gossett*

1421. Quenching Oil
8-page booklet on applications and cost reductions in oil-quenching installations. *Sun Oil*

1422. Quenching Oil
Technical bulletin on quenching oil and accelerators to provide deeper hardening. *Park Chemical*

1423. Radiography
16-page bulletin on materials and accessories for radiography. Density curves for four types of films. *X-Ray Div., Eastman Kodak*

1424. Radiography
Bulletins JR and AR on one and two million volt X-ray generator. *High Voltage Engineering Corp.*

1425. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting." *Molybdenum Corp.*

1426. Recorder
12-page brochure on new recorder for electric and pneumatic transmission systems. *Bailey Meter Co.*

1427. Recorder
12-page bulletin on laboratory recorder that converts manual instruments into automatic, recording instruments. *Fisher Scientific*

1428. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000° F. *Johns-Manville*

1429. Refractories
12-page booklet on gunning practices and BRI gun gives details of history, development and procedures in openhearth and electric steelmaking furnaces and other steel plant operations. *Basic Refractories*

1430. Refractories
New 20-page bulletin on boiler refractories discusses basic requirements of refractories, what causes refractories to fail, various kinds of insulating firebrick. *Refractories Div., Babcock & Wilcox*

1431. Refractories
Bulletin on refractory tile for slot type forge furnace lintel construction. *J. H. France Refractories*

1432. Refractories
40-page book lists super-refractories for heat treating furnaces and gives data on use in different kinds of furnaces. *Refractories Div., Carborundum*

1433. Refractories
24-page booklet on how refractory grain is produced. Chemical and physical characteristics, sizes available, applications. *Norton*

1434. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

1435. Refractory Mixes
16-page bulletin 315 on properties and applications of sillimanite super-refractory ramming mixes and furnace patches. *Chas. Taylor Sons*

1436. Restorer
Catalog R-22 on restorer for detecting and correcting thermocouple circuit failure. *Peerless Electric Co.*

1437. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

1438. Rust Prevention
72-page book on cleaning, preservation, and packaging of metals. Causes of corrosion. *E. F. Houghton*

1439. Rustproofing
Bulletin on compound for rustproofing ferrous metal parts. *American Chemical Paint*

1440. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1441. Salt Baths
32-page booklet on heat treating in liquid salt baths. Properties of several liquid baths. *E. F. Houghton*

1442. Selective Hardening
Article on hardening 75 different parts in one heat treat department at Crown Cork & Seal Co. *Ajax Electric Co.*

1443. Shell Molding
8-page technical bulletin on shell molding process for stainless steel. *Cooper Alloy Foundry*

1444. Sonic Thickness T
Measurement of wall thickness one side by sonic method. *Branson*

1445. Spectro-Analysis
Catalog V3 on excitation units f cision spectrochemical analysis. *Ash*

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8-page booklet on optical emiss rect reading spectographs for pro control and research. *Applied R Labs.*

1447. Spectrograph
12-page bulletin FS-252 on all-el direct-reading spectrograph whic lyzes up to 65 different elements i *Fisher Scientific*

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16-page bulletin on application ponents, for mass spectrometer. dated *Engineering Corp.*

1449. Spectrometer
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1450. Stainless Applicati
Bulletin on advantages of stai the chemical industry; units made cation, design, alloys. *Crucible St*

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28-page technical book on steel bars includes processing i tion about cutting, welding, forgi setting, machining, and heat treat *legheny Ludlum*

1452. Stainless Fastenin
20-page catalog of stainless st screws, nuts, washers, machine sheet metals screws, set screws, tings and specialties. *Star Stainles*

1453. Stainless Steel
44-page book gives detailed info on use of stainless steel in the industries. *Crucible Steel*

1454. Stainless Steel
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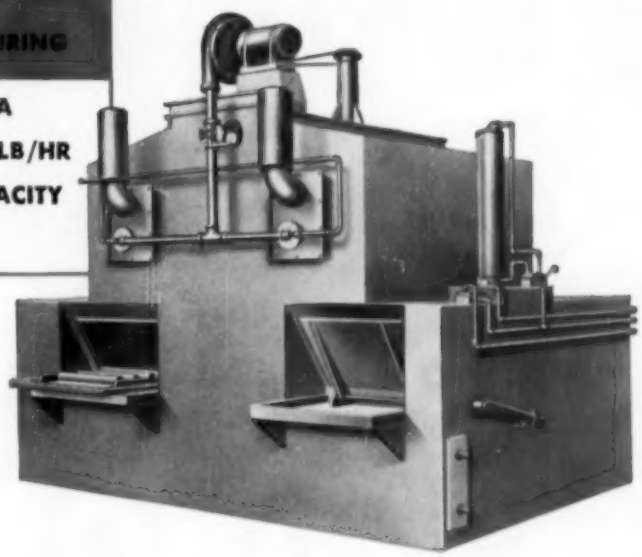

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1459. Straigh
24-page bulletin pipe and tube anal tary machines. *Ma*

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Catalog gives co on subzero metal *Sub-Zero Products*

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1462. Telluri
6-page pamphlet tellurium copper a

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36-page Bulletin tronic instruments dicating variables.

1464. Tempe
Data sheets on op ature control and *Northrup*

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1466. Testing
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1468. Tin Pl
Data on immersi a pure tin coatin *Technic*

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Steel 52100

stock list on 52100 tubing, bars and rgings. *Peterson Steels*

Steel 52100

sheet on high-purity 52100 steel, y vacuum melting. *Vacuum Metals*

Stereomicroscopes

38-page Catalog D-15 shows value e-dimensional microscopes for in- l assembly lines and research lab- es. *Bausch & Lomb Optical*

Straightening

ge bulletin on how to straighten nd tube analyzes two plane vs. ro- achines. *Mackintosh-Hemphill*

Subzero Treatment

log gives complete technical data zero metal treatment. *Cincinnati ro Products*

Super High Speed Steel

er on molybdenum, 8% cobalt high steel for use at speeds 20 to 25% than with ordinary high speed Heat treatments. *Firth Sterling*

Tellurium Copper

e pamphlet on properties of 0.5% m copper alloy. *Chase Brass*

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ge Bulletin P 1245 on new elec- instruments for recording and in- g variables. *Bristol Co.*

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tin 48 on program controllers for tion and quality control testing r research and development. *Tinius*

Testing Machines

tin on Brinell hardness, ductility, ession, tensile, universal, trans- hydrostatic proving instruments. *City Testing Machines*

Tin Plate

on immersion method of applying tin coating on brass or copper. e

1469. Tinning

Bulletin TC-4344I on electrotinning of copper wire. *Baker & Adamson Products*

1470. Titanium Alloy

Data on ternary alloy with 3% aluminum and 5% chromium gives physical properties, forging temperatures, high temperature characteristics. *Mallory-Sharon Titanium*

1471. Titanium Bolt

Bulletin 1473 contains chart and table of fatigue properties of titanium tension bolt. *Standard Pressed Steel*

1472. Titanium Tubing

New bulletin on two grades of titanium tubing and pipe. Advantages and applications. *Carpenter Steel Co., Alloy Tube Div.*

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26-page book on six oil and air hardening steels for high-production tools and dies. Many uses illustrated. *Bethlehem Steel*

1474. Tool Steel Heat Treat

Bulletin 1147EE on electric furnace for heat treatment of high speed tool steel. *Hevi Duty*

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Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

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Data card 177 on analyses of carbon, alloy and stainless tubing steels for elevated temperature and elevated pressure service. *Babcock & Wilcox*

1477. Tubing

52-page "Handbook of Seamless Steel Tubing." 26 pages of data. *Timken*

1478. Ultrasonics

Bulletin GEA-6239 on ultrasonic power generators for industrial cleaning equipment. *General Electric*

1479. Vacuum Metallizing

Reprint "High Vacuum Metallizing of Metals and Plastics." *Consolidated Vacuum Corp.*

1480. Vacuum Metallizing

16-page booklet on properties of metallized coatings, the process, and advantages of metallizing. *F. J. Stokes Machine*

1481. Vanadium Products

12-page brochure on 25 steel, iron, aluminum and chemical products. Composition and applications. *Vanadium Corp.*

1482. Water Softeners

20-page Bulletin 2386-A on water softeners, specifications, operating characteristics and typical installations. *Permutit Co.*

1483. Welding

Three bulletins on recently developed Fillerarc consumable-electrode gas-shielded welding process. *General Electric*

1484. Welding Alloy Steel

44-page Data Book 4D covers all types of welding of nickel alloy steels. *International Nickel*

1485. Welding Copper

24-page booklet on oxyacetylene, carbon-arc and metal-arc welding techniques for copper and copper alloys. *Revere*

1486. Welding Equipment

Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1487. Welding Rods

Catalog lists metals, alloys, powdered metals and processed minerals and ores for the welding rod industry. *Shieldalloy*

1488. Welding Stainless

8-page Bulletin GET-1955 gives arc-welding practices for stainless steels. *General Electric*

1489. Wire Finishing

Bulletin A-105 on continuous patenting, cleaning and coating of steel wire. *Gas Machinery Co.*

1490. Wire Mesh Belts

130-page manual on conveyor design, belt specifications, metallurgical data. *Cambridge Wire Cloth*

1491. Wire Straightening

Bulletin 52-C describes precision machine for straightening small wire with extreme accuracy. Applies to round wire 0.007 to 0.125 in. diameter of ferrous or nonferrous metal. *Continental Foundry & Machine*

1492. X-Ray Equipment

12-page Catalog CH 322/3 on recording X-ray diffractometer. *Jarrell-Ash*

1493. X-Ray Supplies

50-page catalog of industrial X-ray supplies and accessories. *Westinghouse*

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New 24-page booklet on zinc for die castings and applications of die castings. *St. Joseph Lead Co.*

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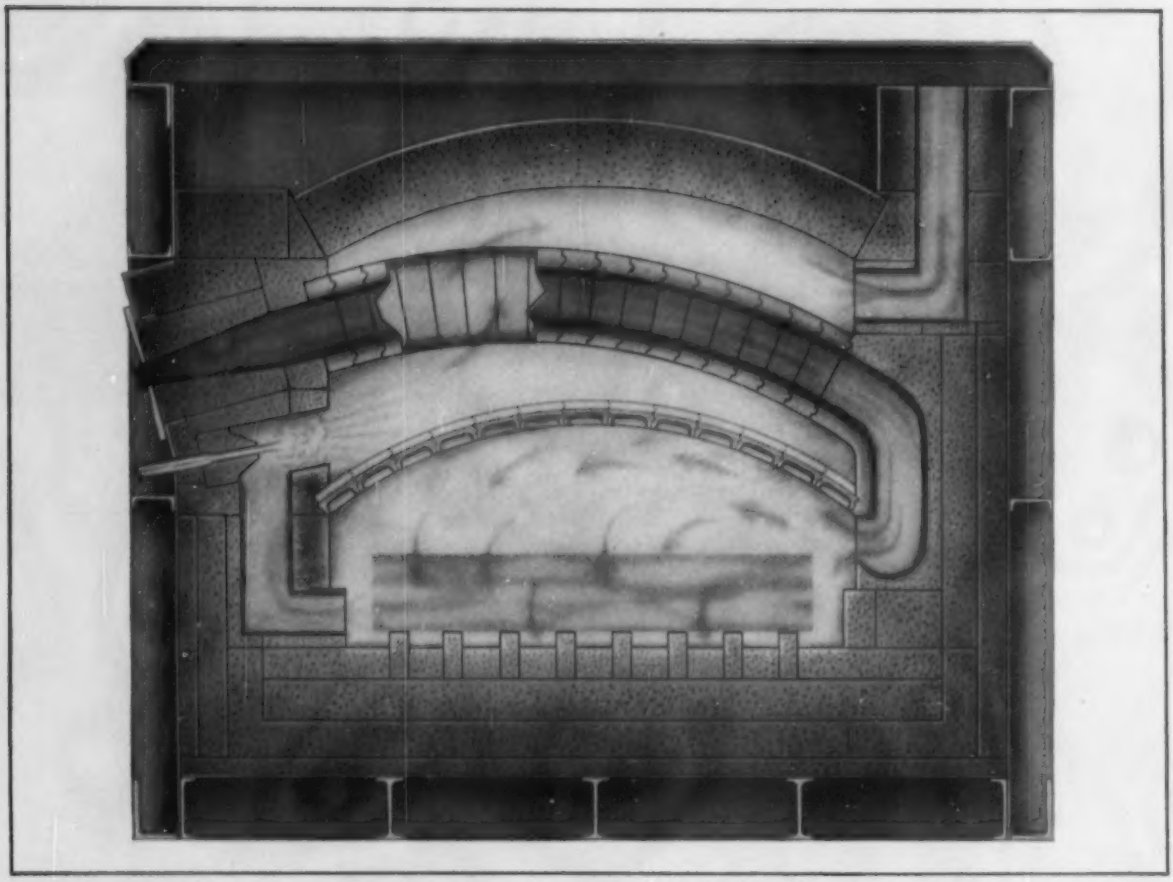


Cross-section of a Lithium Company two-stage hot atmosphere recuperative furnace for scale-free heating of ferrous and non-ferrous metals for precision forging and rolling. The segmented conduit, a Lithium Company design, is made of Norton CRYSTOLON tongue and groove tiles. Fired shapes of this same material form the side walls. Burner block is of ALUNDUM refractory material.

Lithium Company specifies long-life ALUNDUM and CRYSTOLON* refractory shapes for its atmosphere furnaces*

The Lithium Company of Newark, N. J., well-known builder of atmosphere furnaces, reports excellent results from Norton refractories.

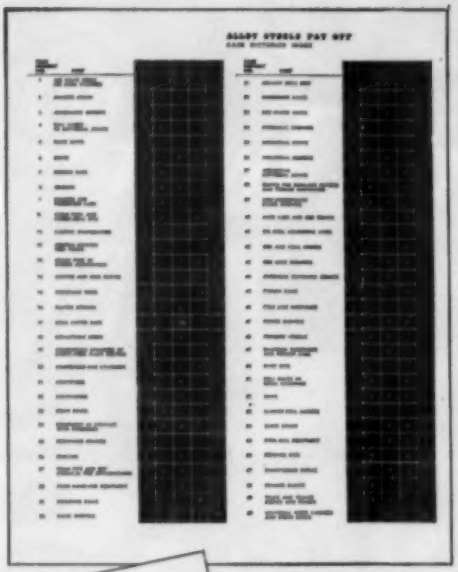
The Lithium designed refractory shapes are Norton CRYSTOLON Silicon Carbide. They were selected for their hot strength, high refractoriness, thermal conductivity, and low thermal expansion. They give long, trouble-free service life at temperatures up to 2900°F. ALUNDUM refractory material was the choice for the burner block because of its high refractoriness and resistance to chemical influences at temperatures up to 3450°F.

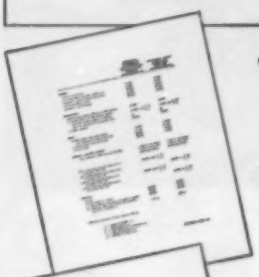
For your own furnace operations

It will pay you to investigate how Norton R's — *engineered and prescribed* refractories — can help you save time, work and money. See your Norton Representative or write to NORTON COMPANY, Refractories Division, 325 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto 5, Ont.

NORTON
REFRACTORIES
Engineered... Rx... Prescribed
Making better products... to make your products better

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

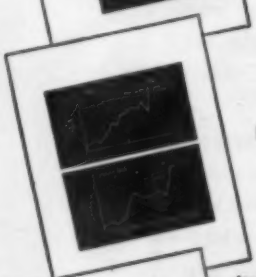




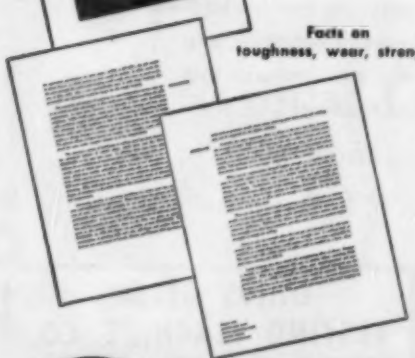
60 fully documented case histories

Facts on maximum pay load

Facts on lower operating costs



Facts on lower corrosion rate



Facts on toughness, wear, strength

CLIMAX MOLYBDENUM COMPANY, Dept. 5
500 Fifth Avenue, New York 36, N. Y.

Please send me the 208-page handbook
"Alloy Steels Pay Off"

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If you use steels, here's the handbook you should have

This fact-packed handbook is a must for you if you use steel. Here, in completely documented form, you'll find how the use of alloy steels adds economies, increases service life, offers many other advantages.* Cost-conscious executives will find the full story on these economies of alloy steel in the first section of the handbook. Designers and metallurgists will find the advantages of alloy steels in the 60 case histories. Get your copy today. Climax Molybdenum Company, 500 Fifth Avenue, New York 36, N. Y.

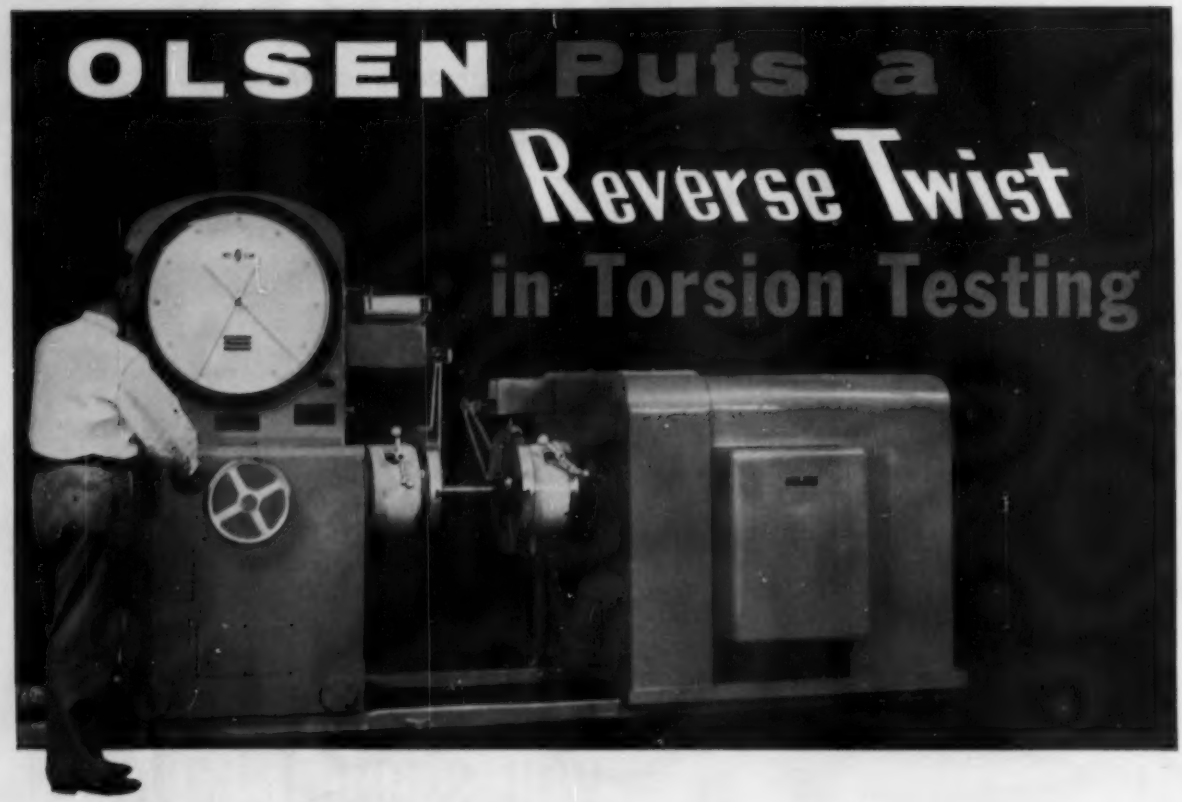
MS5-18

***Advantages of ALLOY STEELS**

- longer life
- greater pay load
- lower operating costs
- greater safety
- less maintenance

CLIMAX MOLYBDENUM

OLSEN Puts a Reverse Twist in Torsion Testing



Torsion testing is not just one, but both directions—*continuously* and with *only one set of grips* . . . and that's only part of the trend setting story about the Double Torsion Testing Machine—a Tinius Olsen Exclusive.

This Olsen torsion machine applies a twist of "X" degrees in one direction of rotation and indicates the load on the Selectrange dial. With the flip of a switch, the machine reverses, applies and indicates any desired twisting load in the opposite direction. At the same time a permanent record of all phases of the test can be made in BOTH directions of rotation with an Olsen Electrical Torsion Recorder.

This amazing torsion machine with its double weighing system is made possible by the Olsen Selectrange electronic indicating system. The applied load is read directly in inch-pounds on the large 28-inch illuminated dial. Full dial scale is available for each capacity range in both clockwise and counter-clockwise rotations. These features, coupled with unmatched ease of operation, and guaranteed accuracy are a few of the many reasons why your first and best choice for torsion testing is an Olsen Double Torsion Testing Machine.

Write for further information

1880 OUR 75th ANNIVERSARY 1955

TINIUS OLSEN TESTING MACHINE CO.
2030 Easton Road · Willow Grove, Pa.
Testing & Balancing Machines

A HALF CENTURY OF SERVICE

to the Iron and Steel Industry

Our half century of service to the metals industry has not been simply a matter of expanding productive capacity, nor producing more of the same.

To a large extent, it has been a matter of developing new uses for materials. It has been a problem of finding better products at lower cost . . . of looking continually for ways and means to help the steel and ironmaker meet the demands of his customers for better metals.

Consider our Research Center, for example. It's the most recent addition in our expansion program designed to broaden our service to the metals industry. This service provides our customers with valuable research information for solving alloy problems posed by today's complex and highly specialized needs.

Because a substantial increase in the use of ferro alloys is essential to meet these growing demands, we have expanded our alloy production facilities. We have modernized and stepped up our mining and milling operations. Existing plants have been modernized. New plants have been built. Today—after a half century of steady growth—we are one of the nation's largest producers of ferro alloys.

Through our product diversification . . . our fully integrated mining, milling and smelting operations . . . our research facilities, we have been able to meet and often anticipate the needs of the iron and steel industry.

We take pride therefore in this half century of service. And we are pointing our resources and the energies of our people to another half century of service.

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Producers of alloys, metals and chemicals

The most ever offered in a

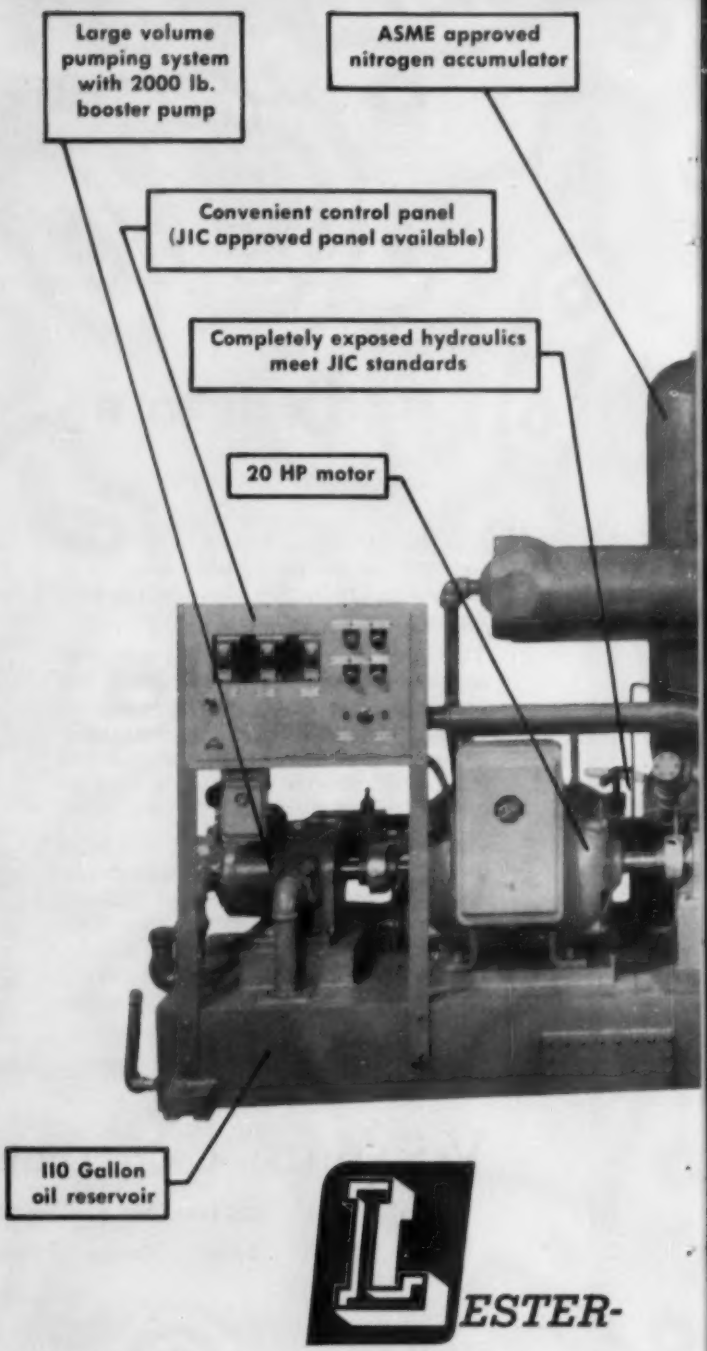
The LESTER-PHOENIX HP-2½X-SF for ALUMINUM DIE CASTING

Now that this new Lester has taken its place in the industry, the conception of a 400 ton die casting machine will have to be revised upward. The HP-2½X-SF has size, shot capacity, speed and unusual ruggedness that makes it—on the basis of any comparison, including price—the leader in its class.

The backbone of this exceptional machine is the solid steel frame assembly which, combined with the massive toggle links, develops 400 tons of clamp—based not on designer's calculations, but on actual strain gauge tests! This basic structure, in turn, permits all of the outstanding features shown here.

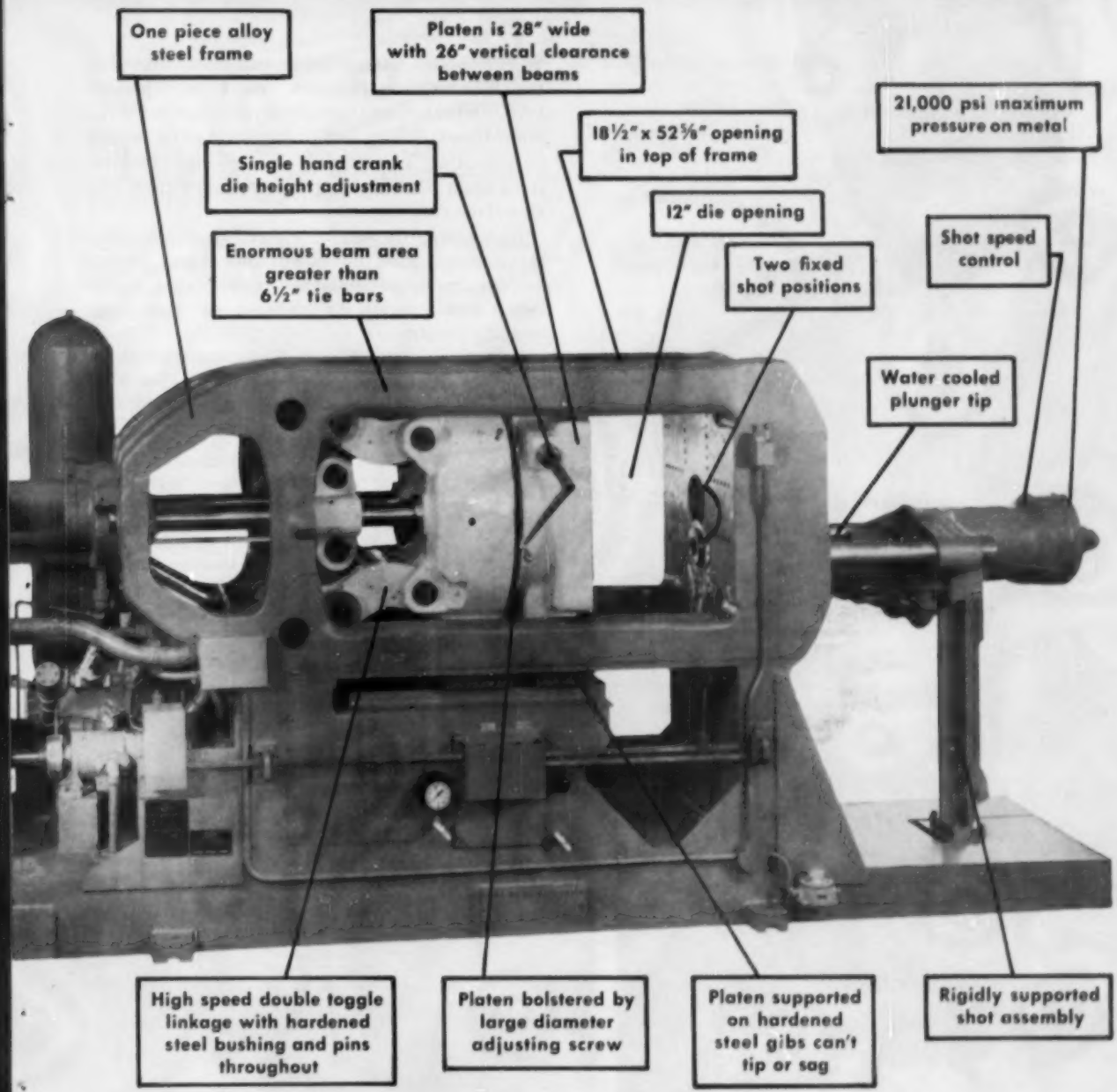
And there are many more: ranging from automatic hydraulic ejection to convertibility to zinc die casting. For complete specifications write today to Lester-Phoenix, and also ask for regular copies of our house organ, "The Lester Press".

The HP-2½X-SF is also offered with the Pre-Fill injection system, increasing maximum shot pressure to 32,000 psi and also increasing shot speed.


Large volume pumping system with 2000 lb. booster pump
ASME approved nitrogen accumulator
Convenient control panel (JIC approved panel available)
Completely exposed hydraulics meet JIC standards
20 HP motor
110 Gallon oil reservoir

LESTER-

400 Ton die casting machine


One piece alloy steel frame
Platen is 28" wide with 26" vertical clearance between beams
18½" x 52⅝" opening in top of frame
21,000 psi maximum pressure on metal
Single hand crank die height adjustment
12" die opening
Shot speed control
Enormous beam area greater than 6½" tie bars
Two fixed shot positions
Water cooled plunger tip
High speed double toggle linkage with hardened steel bushing and pins throughout
Platen bolstered by large diameter adjusting screw
Platen supported on hardened steel gibs can't tip or sag
Rigidly supported shot assembly

DIE CASTING MACHINES

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4-point service

Westinghouse, manufacturer of gas, oil and electric heat-treating furnaces, offers an expanded and comprehensive service to help you get maximum speed, quality and dollar savings from your heat-treating operation. The savings realized stem from Westinghouse ideas, know-how and manufacturing capacity.

In scope, this service ranges from unbiased recommendations of fuel, equipment and control devices through manufacturing, packaged installation and proper maintenance of your heat-treating system.

Call your nearest Westinghouse sales office for complete information . . . ask for *The Man With The Facts* on industrial heat-treating.

Les Gillette, Sales and Order Service Mgr., Westinghouse Industrial Heating Division, explains how this exclusive service brings greater economy to your heat-treating operation.

Westinghouse engineers study your plant arrangement, talk to company engineers and dig into every phase of your heat-treating picture. With unbiased recommendations, these Westinghouse specialists often point out new techniques that could improve operations.

Unique production line techniques permit close quality checks on furnace manufacturer from point of initial materials through final assembly and testing. Above is one in-line assembly and testing area in the Westinghouse Meadville plant.

gives you more heat-treating per dollar . . .

1. Engineering consultation and recommendations—Westinghouse engineers, experienced in all phases of heat-treating, thoroughly analyze your problems firsthand. They'll talk things over with your engineers, then make unbiased recommendations as to type of basic and auxiliary equipment most suitable for your needs.

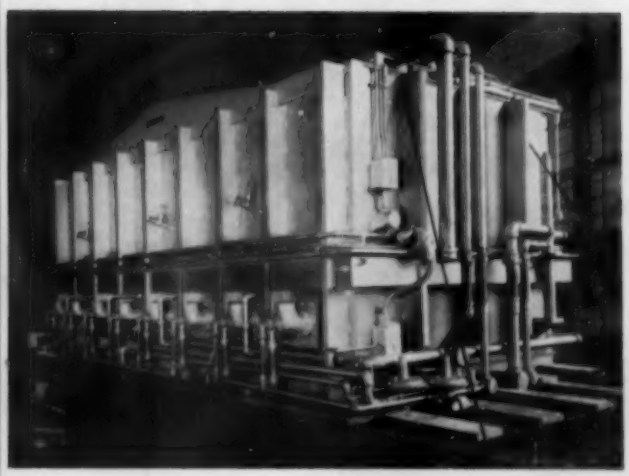
2. Skillful equipment design—Most of our design engineers have at least 14 years' experience in the erection, operation and maintenance of industrial furnaces. This background of factory and field know-how makes advanced and skillful furnace design the rule at Westinghouse . . . design that assures heat-treating to highest quality, speed and economy standards.

3. Quality manufacturing techniques—Furnaces tailored to your requirements are manufactured entirely within the Westinghouse plant on a production line procedure. This means close quality checks, by experts, during every step of assembly . . . means packaged equipment and pinpointed responsibility.

4. Unique packaged installation — Installation of completed equipment is done in one quick operation. Everything is shipped intact . . . no assembly work required in your plant. Westinghouse installation teams are thorough and efficient. What's more, Westinghouse engineers establish maintenance procedure for you and check back periodically to assure peak efficiency from equipment. J-10438

YOU CAN BE **SURE**...IF IT'S

Westinghouse



Westinghouse ships erected furnace sections with parts fitted and matched. This pre-packaged shipment saves you storage and handling problems. Westinghouse will supervise or undertake complete furnace erection and installation, thereby assuring peak operating efficiency.

Put this service to work for you! For more information, mail this coupon or call your nearest Westinghouse Sales Office.

Westinghouse Electric Corporation
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☐ Please have your representative call

☐ Please send more information on your new heat-treating service

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Company _____

Address _____ State _____

Whatever your furnace needs for control—

There's good reason why more heat-treating furnaces everywhere are controlled by Brown instruments. First, of course, is performance . . . sensitive, precise control that meets the most exacting requirements of modern heat-treating techniques. And equally important is versatility. In this varied line of instrumentation you'll find just about everything a furnace could possibly need in the way of control.

Choose *ElectroniK* Strip Chart Controllers for detailed, long-term records . . . and a selection of control forms including electric systems of the contact, position-proportioning (*Electr-O-Line*) and time-proportioning (*Electr-O-Pulse*) types; and pneumatic control from two-position to full proportional-plus-reset-plus-rate action.

Choose *ElectroniK* Circular Chart Controllers for ease of scale reading . . . convenient daily charts; in a full range of electric and pneumatic control forms.

Note: the basic components of all *ElectroniK* models are interchangeable . . . to simplify and speed up service.

Choose *ElectroniK* Circular Scale Controllers where you want readability and control check at extreme distance . . . without need for a record. Supplied with all contact and proportional types of electric control.

Note: all *ElectroniK* models are available in both Standard and Precision Series.

Choose *Pyr-O-Vane* Controllers where you don't need a record but do need precise vane type snap action electric control by a millivoltmeter instrument . . . also available with pulse-type time proportioning action, in both vertical and horizontal models.

Choose *Protect-O-Vane* Controllers for simple, dependable excess temperature cut-off protection . . . can be used with any temperature control to prevent furnace shut downs and loss of production.

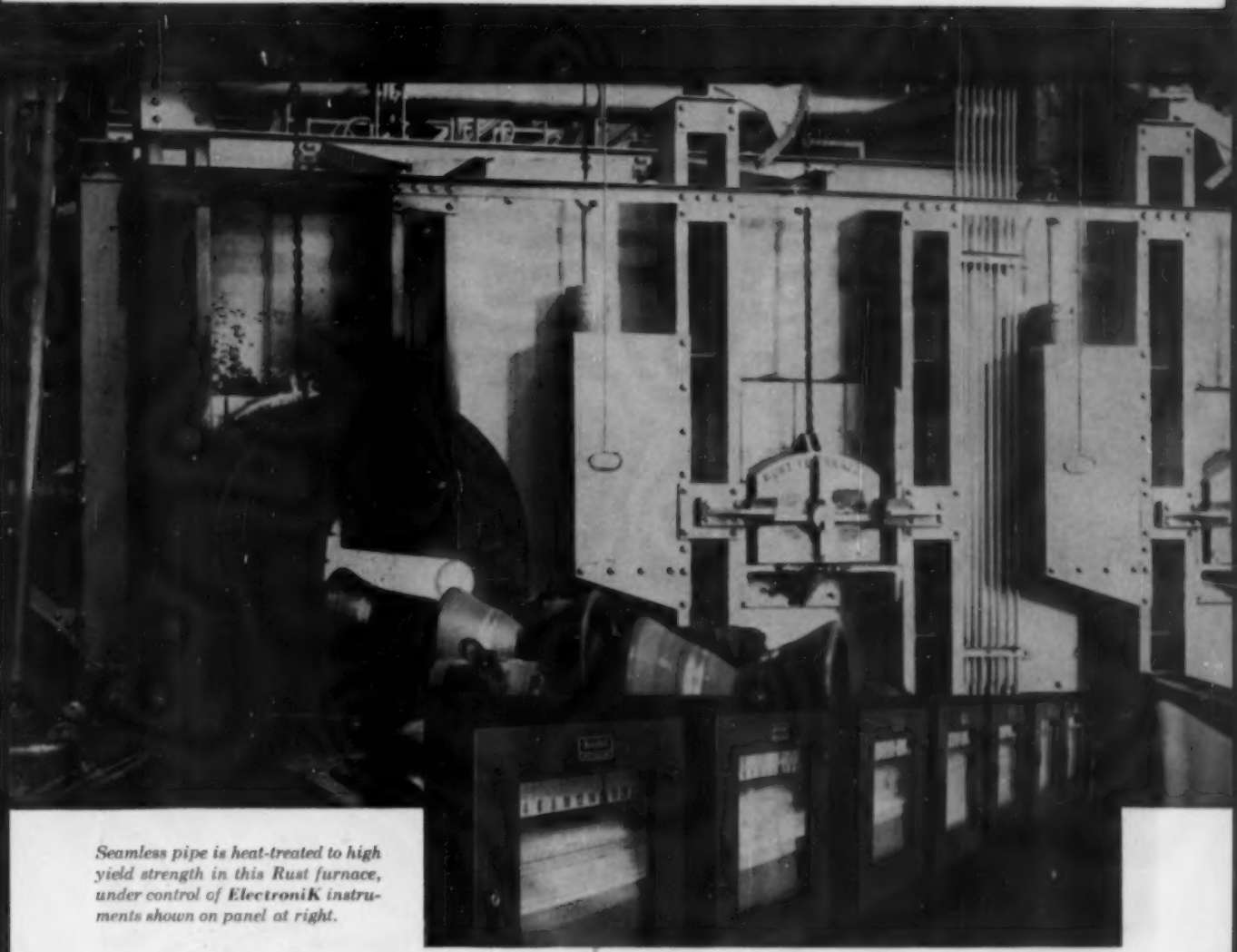
* * *

And for all your pyrometer supplies, investigate the convenience and economy advantages of the HSM Plan.

Annealing of J & L high-strength tube *utilizes precision*

•

Complete data on the many models of ***ElectroniK*** *instruments and electric and pneumatic control systems is summarized in Catalog 1531,* ***"ElectroniK Controllers."*** *Write for your copy today.*



Seamless pipe is heat-treated to high yield strength in this Rust furnace, under control of ***ElectroniK*** *instruments shown on panel at right.*

of *ElectroniK** *temperature control*

DESTINED for use in deep oil wells, high-strength seamless tubing made in Jones & Laughlin's Aliquippa, Pa. plant is the product of modern metallurgical technology. One of the most critical operations in the production process is the initial heating, which must be a good uniform soaking heat at 1600 F. Then the pipe is quenched and put through a second furnace and tempered at proper temperature to give the high yield, toughness and ductility necessary to meet the strength requirements for deep well pipe.

The high heat and temper furnaces are Rust Furnace Company walking beam type furnaces. To get the required temperature precision, each furnace has eight separate zones, each of which has its individual *ElectroniK* control. The instruments incorporate *Electr-O-Line* electric proportioning control relays, which regulate the gas valves for the zone burners.

The complete proportioning—plus—reset action afforded by this control system makes adjustment of heat input prompt and precise . . . keeps heating and soaking temperatures right on the line regardless of changes in rate of tube production, gas pressure, draft, outside temperature or any of the dozens of factors which might cause variations.

Whenever you're planning a new furnace or modernizing present equipment, plan to take advantage of the performance that *ElectroniK* instrumentation can give you. Complete, individually engineered control systems are available to work with any furnace, whether fuel-fired or electric. Your local Honeywell sales engineer will be glad to discuss your specific requirements . . . and he's as near as your phone. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

● **REFERENCE DATA:**
Write for Catalog 54-1, "Furnace and Oven Controls". . . and for Catalog 1531, "*ElectroniK* Controllers."

*Trademark of Minneapolis-Honeywell Regulator Company

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

First in Controls

In soaking pits, Johns-Manville Sil-O-Cel C-22 Insulating Brick provide outstanding performance as back-up insulation.

Specify
Johns-Manville SIL-O-CEL C-22 Insulating Brick

the diatomaceous silica brick that retains its high cold crushing strength of 700 psi throughout normal service range

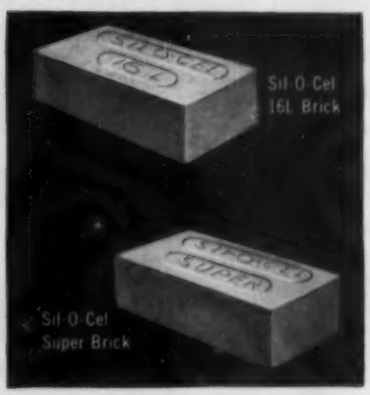
Because of its exceptional strength Sil-O-Cel C-22 Insulating Brick has gained wide acceptance as an all-purpose insulating brick. It is especially recommended for soaking pits, open hearth bottoms, slab heating furnaces, hot blast stoves, coke ovens and other high temperature equipment.

Millions of microscopic cells provide Sil-O-Cel C-22 brick with excellent heat resistance up to 2000F. It has a thermal conductivity of only 1.88 Btu in/sq ft/F/hr at 1000F mean temperature. In addition, with a density of 38 lb/cu ft, it is light and easy to handle.

For direct exposure or back-up to 1600F, use Sil-O-Cel 16L Insulating Brick. This newest member of the J-M diatomaceous silica insulating brick family has *less than 0.1% reversible thermal expansion at 1600F.* Conductivity is 1.07 Btu in/sq ft/F/hr at 1000F mean temperature with a density of 33-35 lb/cu ft. Cold crushing strength is 350 psi. Sil-O-Cel 16L serves equally well as back-up insulation or exposed refractory lining.

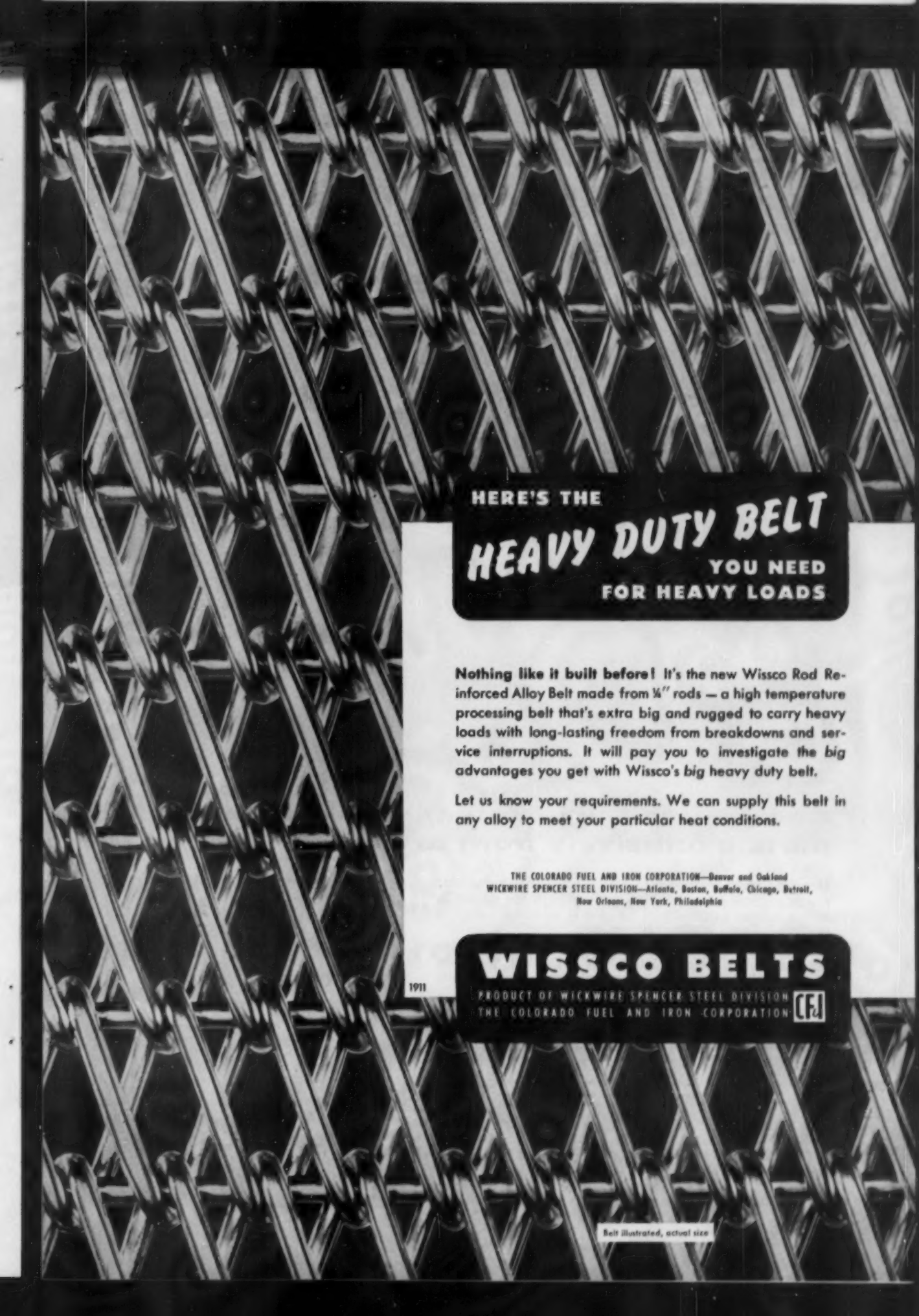
For back-up at higher temperatures, specify Sil-O-Cel® Super Insulating Brick with an unusually high temperature limit of 2500F.

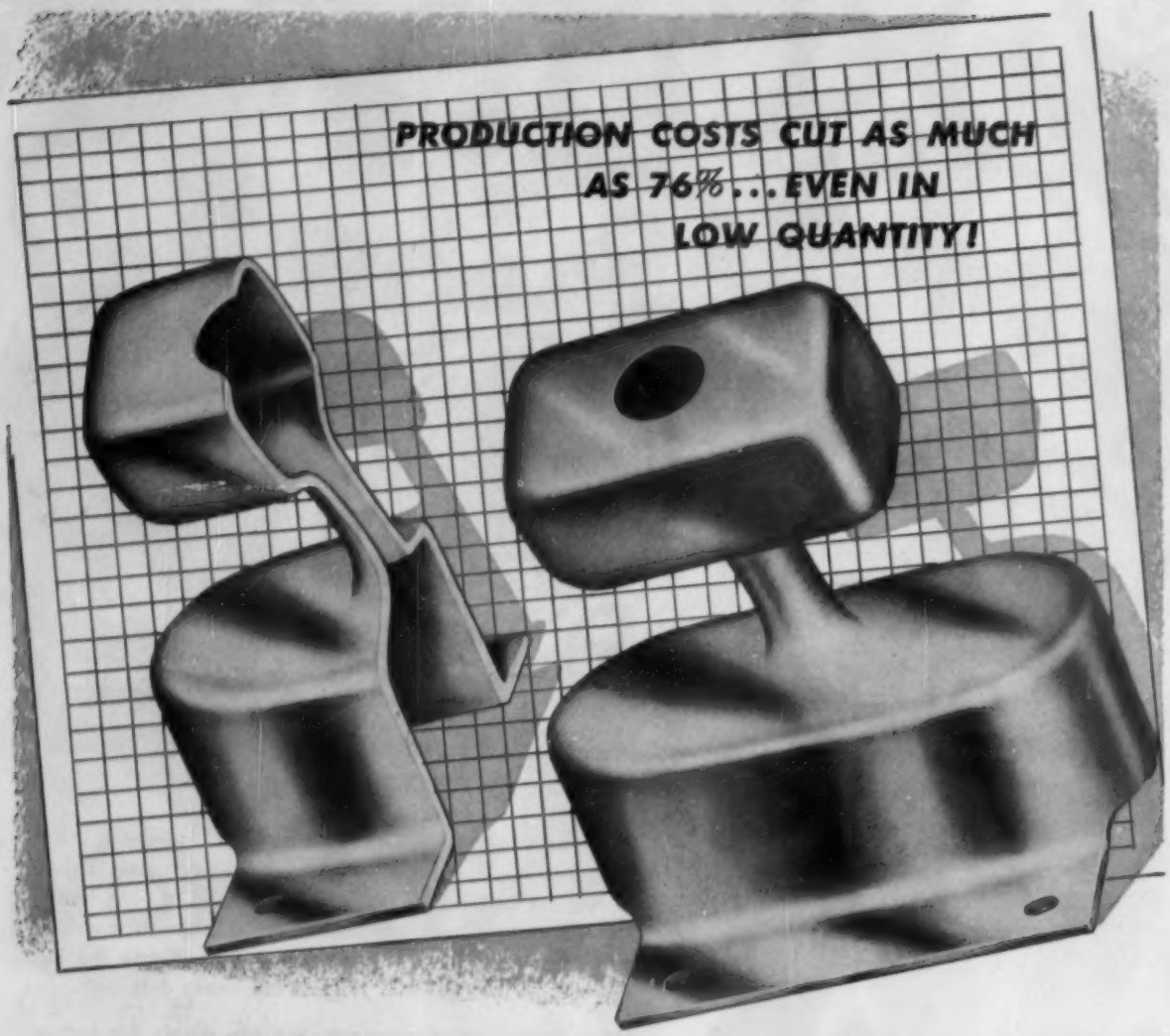
Write today for further information on Sil-O-Cel Insulating Brick and Insulating Fire Brick. Ask for Brochure IN-115A. Address Johns-Manville, Box 60, New York 16, N. Y. In Canada, 565 Lakeshore Road East, Port Credit, Ontario.



Johns-Manville *first-in* **INSULATION**

MATERIALS · ENGINEERING · APPLICATION


HERE'S THE
HEAVY DUTY BELT
YOU NEED
FOR HEAVY LOADS
Nothing like it built before! It's the new Wissco Rod Reinforced Alloy Belt made from ¼" rods — a high temperature processing belt that's extra big and rugged to carry heavy loads with long-lasting freedom from breakdowns and service interruptions. It will pay you to investigate the big advantages you get with Wissco's big heavy duty belt.
Let us know your requirements. We can supply this belt in any alloy to meet your particular heat conditions.
THE COLORADO FUEL AND IRON CORPORATION—Denver and Oakland
WICKWIRE SPENCER STEEL DIVISION—Atlanta, Boston, Buffalo, Chicago, Detroit, New Orleans, New York, Philadelphia
1911
WISSCO BELTS
PRODUCT OF WICKWIRE SPENCER STEEL DIVISION
THE COLORADO FUEL AND IRON CORPORATION
CFI
Belt illustrated, actual size



Complicated investment cast magnesium parts exclusively from Arwood

Shapes impractical or expensive to obtain by conventional methods can now be produced economically by investment casting in magnesium as well as other metals. Arwood can cast, at substantial savings to you, complex parts in difficult-to-form alloys.

Arwood's investment casting process quite often makes possible casting several sub-assemblies into a single part. On many parts, long cored sections can be cast with no draft. Dense, fine-grain parts require only minimum machining.

Our engineers will be pleased to go over your parts problems with you and help cut your own costs. Why not submit parts or prints to us for quotations? Consultation is free of obligation, of course.

Write for free literature describing the investment casting process.

CASE STUDY

METAL: Magnesium (QQ-M-55 Comp. AZ-92-A)
PARTS: Designed and cast as single unit.
QUALITY CONTROL: Chemical and Physical affidavits furnished. Test Bars submitted. Produced under X-ray control.

ADVANTAGES: (as investment casting) Cost drastically reduced. Light weight. Smooth surfaces—no welding seams or parting lines.

ARWOOD

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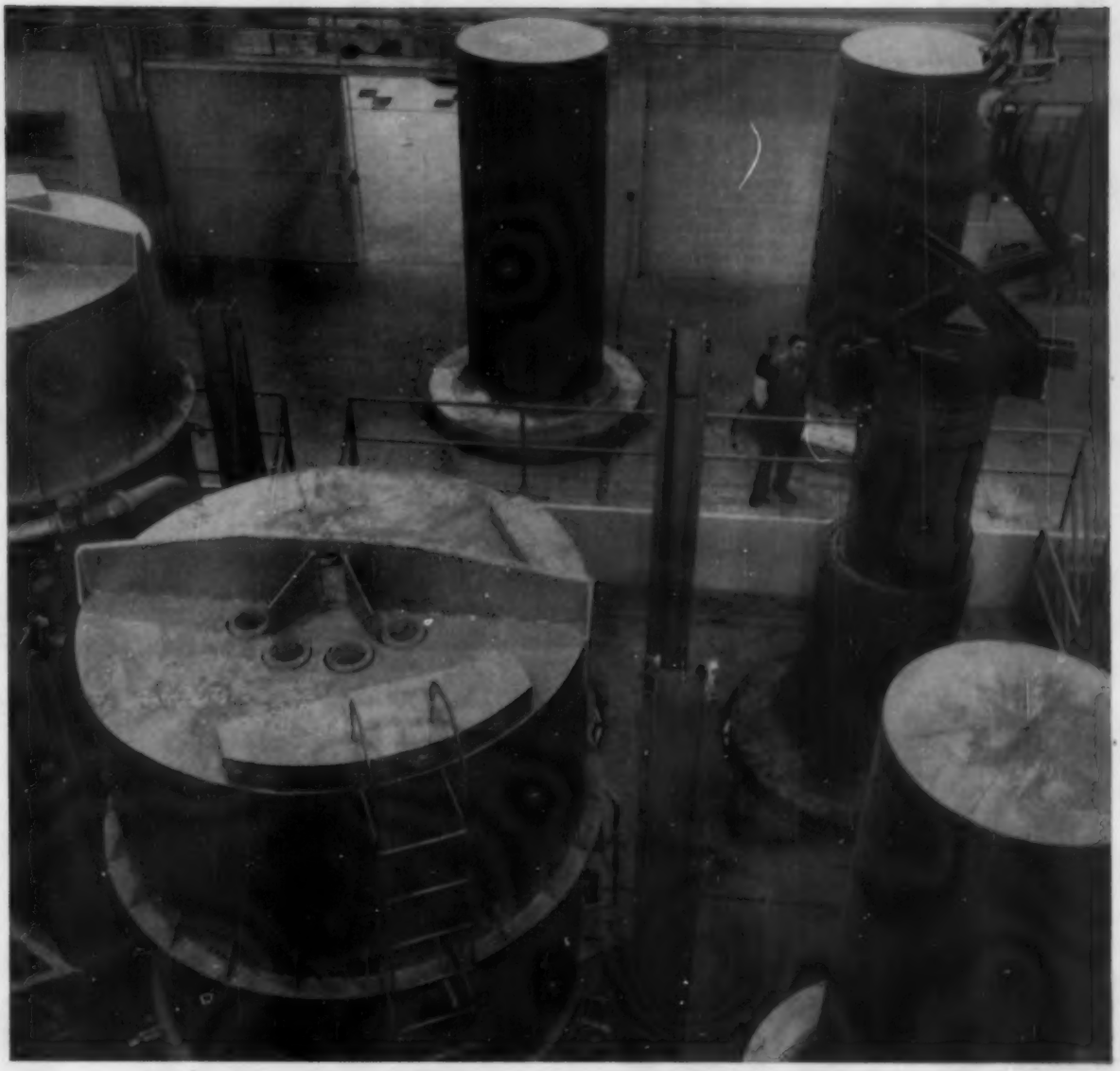
PLANTS: Brooklyn, N.Y.; Groton, Conn.; Tilton, N. H.; Los Angeles, Calif.



Thompson Wire Company anneals cold rolled strip with *GAS*

These are Gas-fired annealing facilities at Thompson Wire Company, Baltimore, Maryland. Here, modern industrial Gas equipment anneals cold rolled strip and assures proper quality for a variety of applications.

Coils of strip are placed one on top of the other on a stationary base. Then, a portable Gas-fired bell furnace is lowered over the stacked coils. Twelve Eclipse Gas burners heat the coils to the proper annealing temperature in a prepared inert gas atmosphere released from inner cones. After firing, the furnace is lifted from the base and replaced with a cooling hood which helps slow down and equalize the cooling rate. Finally, the hood is removed and the coils of strip are lifted from the base.

With Gas, Thompson Wire Company can anneal up to 50,000 pounds of strip in 36 hours. Thompson Wire also uses Gas for water heating.

For further information on how Gas can help you in your heat treating operations, call your Gas Company Industrial Specialist. He'll be glad to discuss the economies and results Gas and modern Gas-fired industrial equipment can provide. *American Gas Association.*

Electric furnace roofs at

THE TIMKEN ROLLER BEARING COMPANY

are bonded with

TAYCO-40 SILICA CEMENT

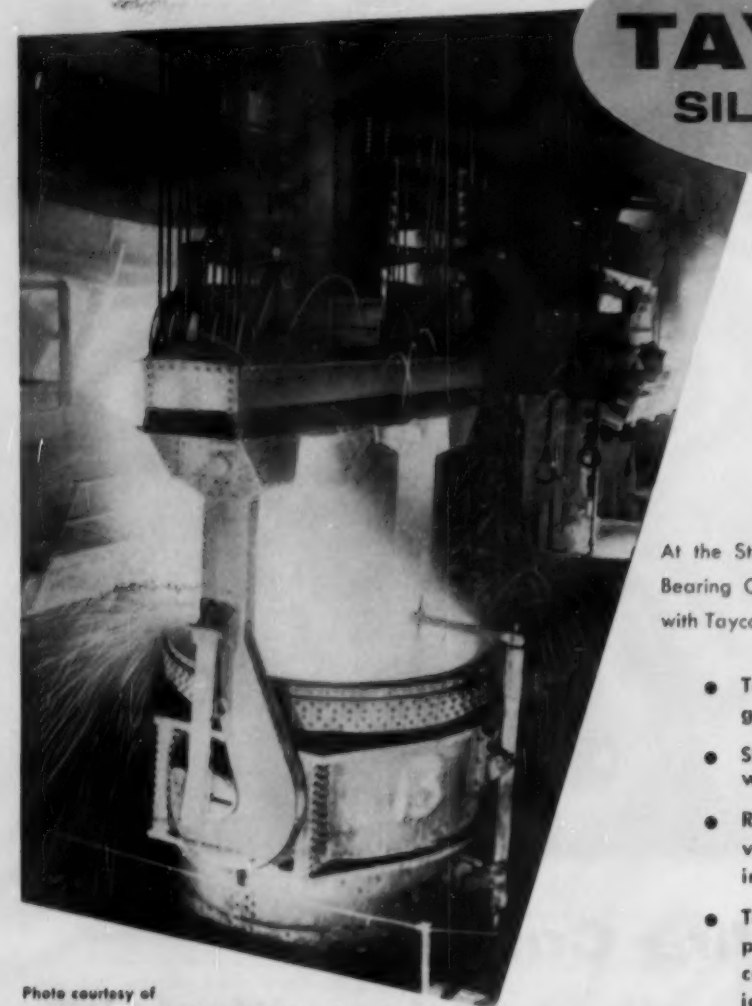


Photo courtesy of
The Timken Roller Bearing Company

At the Steel and Tube Division of The Timken Roller Bearing Company, electric arc furnace roofs are laid with Tayco-40 Silica Cement. The advantages are many:

- **Tayco-40 is nearly as refractory as the best grades of silica or super-duty silica brick.**
- **Silica brick and shapes are more easily fitted with all voids and irregularities well filled.**
- **Roof life is prolonged. Thin, tight joints prevent brick from slipping out of place when in service. Spalling is retarded.**
- **Tayco-40 has excellent water retention properties. It is the most workable silica cement obtainable. Less cement is used; joints are thinner, tighter.**

Tayco-40 is used and endorsed by superintendents of leading steel mills for lengthening the life of silica electric furnace roofs and side walls; for open-hearth furnace roofs, and all other places in open-hearths where silica brick are used. Try Tayco-40 for your next rebuild. Detailed data given in Bulletin No. 507. Ask your Taylor Field Engineer or write direct for your copy.

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REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

The CHAS. TAYLOR SONS Co.
A SUBSIDIARY OF NATIONAL LEAD COMPANY
REFRACTORIES SINCE 1864 • CINCINNATI • OHIO • U.S.A.

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FAHRALLOY...

SETS THE PACE WITH PRICE REDUCTIONS ON SOLUTION POTS

Once again Fahralloy demonstrates with positive action its leadership in the alloy field with sweeping price reductions on most sizes of solution pots. This major step in pricing came about as a result of a review by Fahralloy management of the whole cost picture ranging from material purchasing through production methods. Fahralloy is proud to be able to announce these price reductions, and proud to be able to make them without sacrificing product quality in any way. Here, once again, is clear evidence that proves why you can always look to Fahralloy for leadership in the alloy field. Send for a firm quotation today.

Write for Fahralloy Solution Pot Bulletin 110 for detailed information.

THE FAHRALLOY CO.

150th & Lexington Ave. — Harvey, Illinois

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MAGNESIUM

Lightness in equipment saves manpower when materials are on the move

That's why magnesium is being used more and more to build lightweight but rugged materials handling equipment —to save manpower. Dockboards, platform trucks and hand trucks are just a few of the many applications where magnesium's light weight has increased efficiency and saved money.

One fourth the weight of steel, one third lighter than aluminum, magnesium has simplified design problems while maintaining maximum strength required. Fabrication is also made easier by the excellent weldability, forming, drawing and machining characteristics of magnesium.

To the equipment purchaser, "Made of Magnesium" assures peak efficiency in operation. To the equipment manufacturer, magnesium has become the key to more useful products, greater volume and complete customer satisfaction.

For further information about magnesium, call your nearest Dow sales office, or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. MA 317F.

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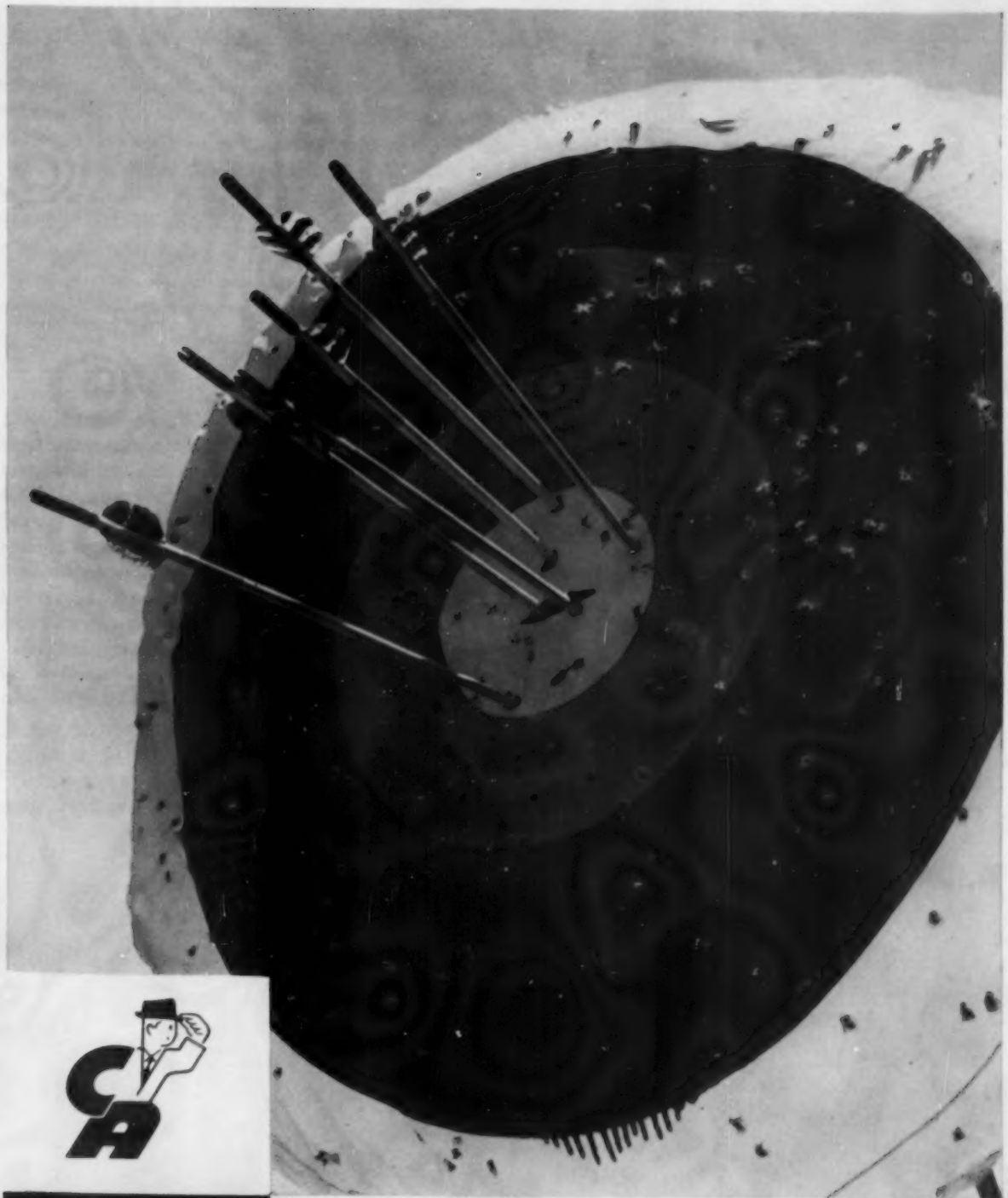


advanced know-how makes the difference...

Advanced know-how makes the difference

Hitting the target in any field of endeavor is the result of know-how based on experience and experiment . . . of knowledge, skill, imagination and an intangible spirit that seeks perfection. These are the things which make the difference between routine and creative handling . . . between success and failure. Here are the highlights of casting methods which show how advanced know-how at Cooper Alloy has made it possible to produce intricate stainless steel parts to quality standards formerly considered impossible.

SHELLCAST®

The development of methods for producing cast shapes in thin, light weight, resin-bonded shells represents a most revolutionary change in the foundryman's art. Like most inventions it was born of the necessity to produce molds faster, more economically and with greater accuracy . . . and to cast parts to closer tolerances, with superior surface finish, greater legibility of markings and better appearance, as well as with thinner sections, small cored holes, well detailed contours, minimum draft and intricate recesses. These advantages are available to design engineers and manufacturers who take advantage of our *advanced know-how* and specify—"Shell-cast by Cooper Alloy"—for their stainless steel components.

SHELLCORE

In some cases the interior surface of the casting is even

JET ENGINE SUPPORT — produced by Shellcast® method, in alloy type 18-8SMO (316)—modified. Weight 35 lbs.

INSTRUMENT HOUSING — produced by combining Shellcast® and shellcore methods, in alloy type 18-8S (302). Weight 1 lb.

JET AFTERBURNER COMPONENT—produced by coremold method, in 12% chrome alloy (tool steel). Weight 11 lbs.

more critical than the exterior, and the core rather than the mold, becomes the big problem. The answer lies in the production of hollow cores by the most intricate methods. Specially designed metal core boxes are used in conjunction with core blowing equipment to produce hollow "shell cores" of superior accuracy and fine detail. These cores fit the mating molds much more closely than sand cores ever could. When it comes to extremes of tolerances—inside and out—Cooper Alloy *advanced know-how* with shell molds and shell cores makes the difference.

COREMOLD

For most castings, the standard sand mold is adequate, but when specifications demand extreme smoothness of surface and close matching of many components, the use of special core mold assemblies becomes necessary. Core sand can be baked hard and when used for making molds it produces an excellent mating surface for cores and assures extra smoothness to the casting surface. Coremolding is a technic widely used for aircraft parts where intricate sections have to be mated and tolerances are close. Cooper Alloy *advanced know-how* puts coremold methods at your disposal.

CENTRIFUGAL CASTING

Casting centrifugally is a procedure offering very specific advantages, including the ability to cast very thin, light weight airfoil sections. The spinning action promotes favorable directional solidification and helps purge castings of impurities. Whether made in metal molds or in sand, castings by the centrifugal method meet highest quality standards, particularly when backed up with the Cooper Alloy *advanced know-how* which has grown out of an unsurpassed intimacy with the process ever since its inception.

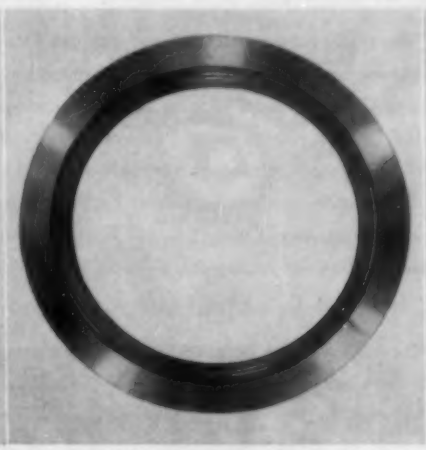
SAND CASTING

The heart of the foundry industry still lies in the production of quality castings in sand molds. But so important is the engineering, the patternmaking, the heading and gating, melting, molding, pouring, heat treatment, pickling . . . so critical is the use and application of x-ray, zyglo, gamma ray, pressure testing . . . so variable are the multiple of control items involved in the pouring of almost thirty different high alloys . . . that even in the production of castings by "conventional methods" quality depends on experience. Here too, Cooper Alloy leadership is your guarantee of the *advanced know-how* that makes the difference.

Tomorrow is ever with us . . .

Our search for new and better ways to produce quality stainless steel castings more economically, for new materials to resist corrosion or abrasion, for new products to answer the needs of the process and metalworking industries . . . goes on continually. Research links us with tomorrow and assures you of the best in thinking, the best in technology. Cooper Alloy *advanced know-how* can make the big difference in your product. Your inquiries are invited.

SUPERCHARGER DIAPHRAGM — produced by centrifugal casting method using coremolds, in alloy type 25-20 (310). Weight 25 lbs.



JET ENGINE RING—produced by centrifugal method using permanent metal molds, in alloy type 23-12W.

CHEMICAL AGITATOR — produced by sand casting method, in alloy type 18-85 (302). Weight 2900 lbs.

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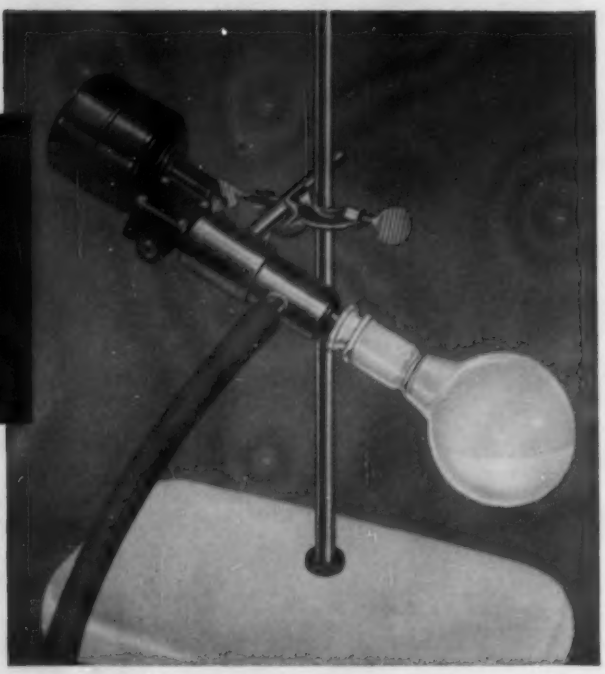

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(Patent Applied For)

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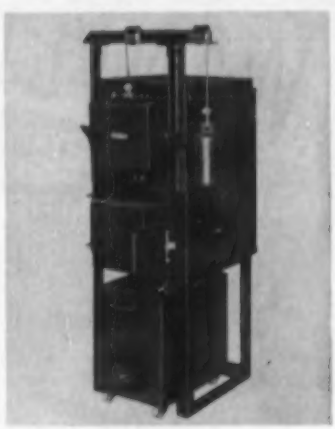

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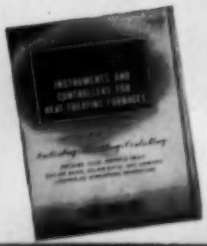

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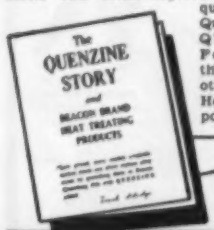

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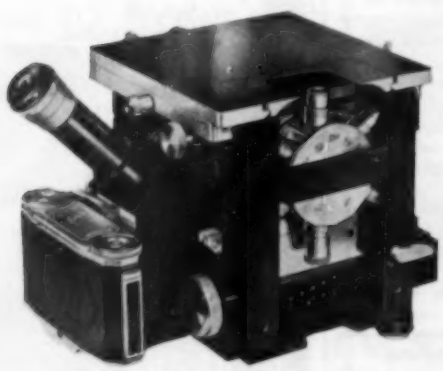

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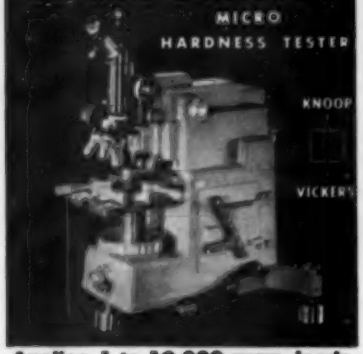

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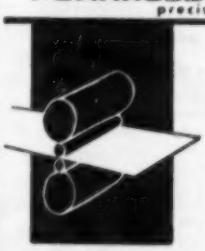

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PENN PRECISION PRODUCTS, INC.

501 Crescent Avenue • Reading, Penn.
Phone: Reading 6-3821

LIST NO. 126 ON INFO-COUPON PAGE 60

Call on Mr. Electrode

See Maurath, Inc. For

Stainless and Heat Resistant ARC WELDING ELECTRODES

• • •

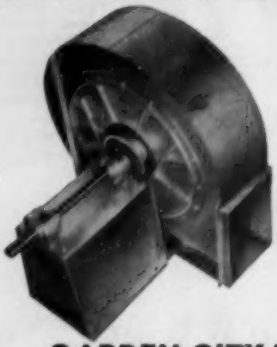
AUTOMATIC WELDING
All Analyses - Coated, Straightened - Cut - Coiled and Spooled

MAURATH, Inc.

21830 MILES AVENUE
NORTH RANDALL 22, OHIO
Phone: MOntrose 2-6100

LIST NO. 72 ON INFO-COUPON PAGE 60

GARDEN CITY Industrial FANS



For a wide choice . . . GARDEN CITY FANS designed with FORWARD — BACKWARD — or RADIAL BLADES, serve many industrial processing requirements.

If your needs call for HIGH TEMPERATURES (300° to 1600°F) you'll find GARDEN CITY HIGH TEMPERATURE FANS save you money. Patented air-cooled shaft slices maintainence costs.

Send for our latest catalogs, illustrating GARDEN CITY INDUSTRIAL FAN equipment. For specific details, outline your fan problems to us, giving cubic feet per minute, static pressure, and just how you intend to use the fan. We'll be pleased to suggest a fan for you.

GARDEN CITY FAN COMPANY

332 South Michigan Avenue — Chicago 4, Illinois

Representatives in principal cities

OUR DIAMOND 75th ANNIVERSARY

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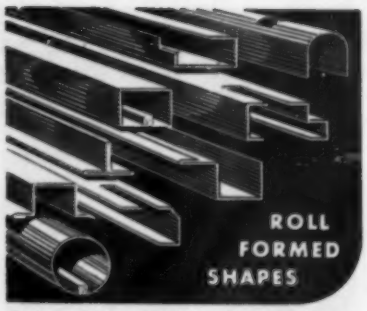

Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

ROLL FORMED PRODUCTS CO.

MAIN OFFICE AND PLANT
3761 OAKWOOD AVE. • YOUNGSTOWN, OHIO

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ARDCOR *Engineered*

TUBING ROLLS
AND
FORMING ROLLS

To Your Specifications or Ardcor Design—for all makes of machines

DESIGNERS AND MANUFACTURERS: All Sizes and Spindle Diameters of Roll Forming Machines, Welded and Lock-Seam Pipe and Tube Mills • Forming Rolls, Tubing and Pipe Rolls • Straightening, Pinch and Leveller Rolls • Cut-off Machines

American ROLLER DIE CORPORATION

29550 Clayton Avenue • Wickliffe, Ohio

LIST NO. 57 ON INFO-COUPON BELOW

WHITELIGHT

MAGNESIUM

your comprehensive independent source of magnesium alloy

Tubes • Rods • Shapes • Bars Hollow Extrusions • Plate • Sheet • Pipe • Wire • Welded and Riveted structures and assemblies

WHITELIGHT MAGNESIUM

WHITE METAL ROLLING & STAMPING CORP.

82 Moultrie St., Brooklyn 22, N. Y.

Sales Office
376 Lafayette St., New York 3, N. Y.

LIST NO. 67 ON INFO-COUPON BELOW

READERS' INFO-COUPON SERVICE, METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

Please send further information, as checked at the right, on the advertisements in the Bulletin Board with numbers I have listed below—

(Bulletin Board Item Number)	(Please check) Send Catalog or Engineering Data	Send Price Info	Nearest Source of Supply
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Your Name _____ **Title** _____

Company _____

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Are parts machined for you under **STATISTICAL QUALITY CONTROL?**

At Non-Gran, they will be. Our contract machine work is performed under industry's newest approach to better products, at lower cost. Write! **AMERICAN NON-GRAN BRONZE CO., BERWYN, PA.** *Metropolitan Philadelphia.*

PRECISION MACHINE WORK
NON-GRAN
CASTINGS • YARD & CENTRIFUGAL

Write for book "Our Story in Pictures"

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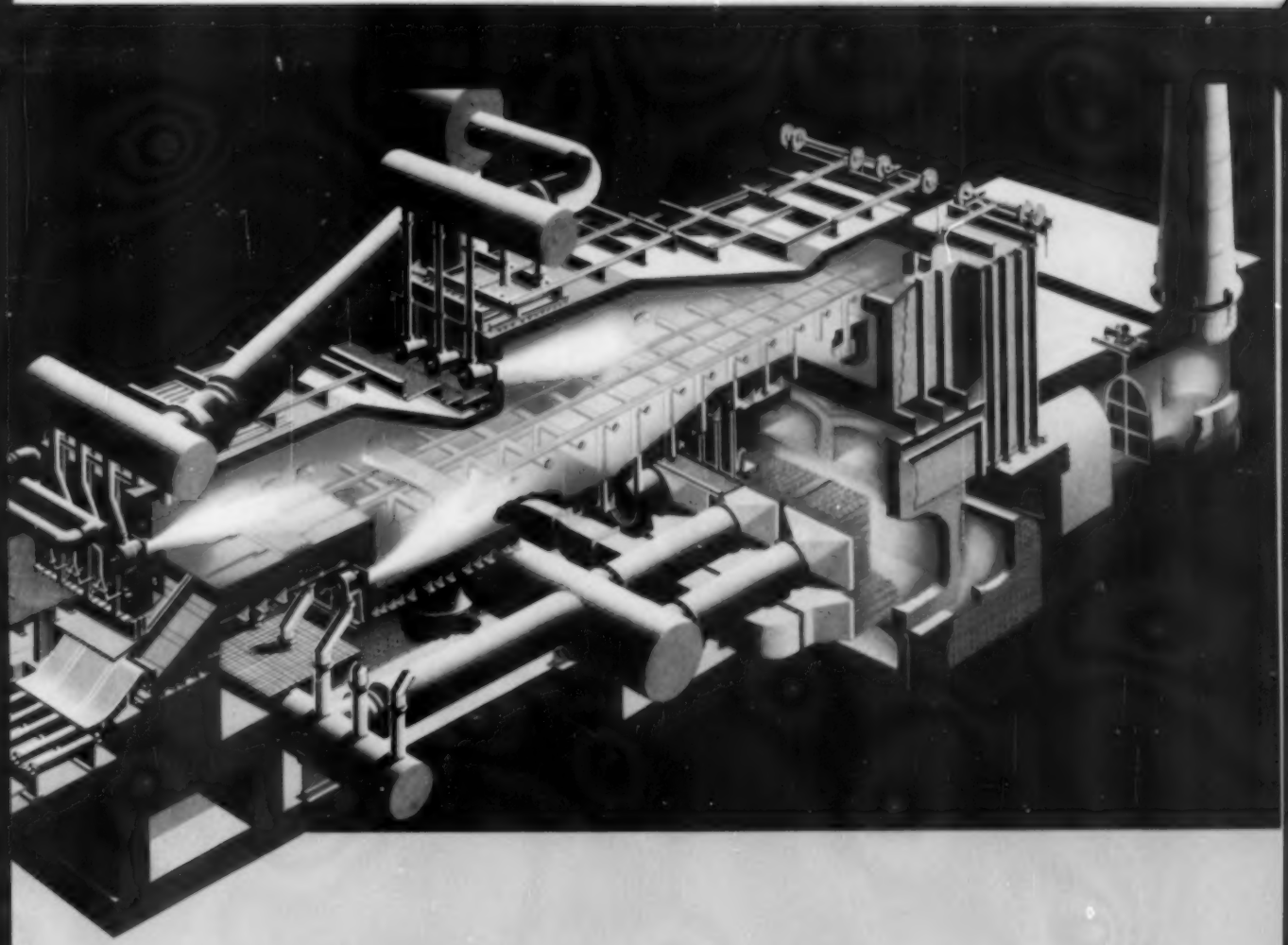


Prime example of Salem-Brosius' furnace-engineering ability

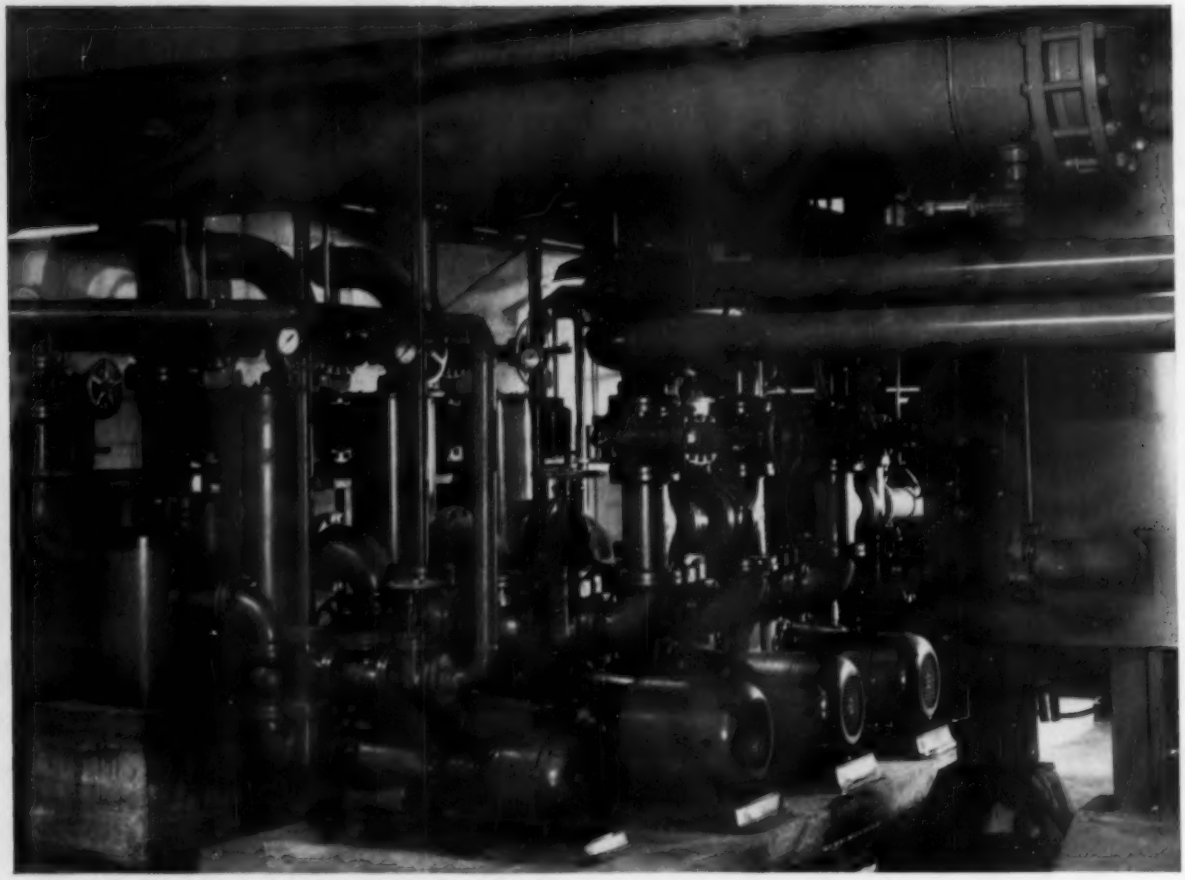
The huge industrial furnace illustrated here attests to the superior engineering skill of Salem-Brosius. One of a few of its kind in the country, it is a pusher-type, triple-fired slab heater currently feeding the giant hot strip and sheet mills of a great steel producer. It features high capacity heating and soaking zones, heavy construction, recuperators for fuel economy, dual gas-oil fuel system, and many other advantages to assure positive, automatic control of furnace output and heating quality. *And the efficiency, economy, ease-of-operation, and trouble-free service this furnace represents are typical of all the furnaces Salem-Brosius builds.* Whether you require conventional heating or heat treating furnaces or furnaces to do an extraordinary job, Salem-Brosius offers equipment designed, engineered, and built not merely as a furnace but as a heating machine. You can purchase these furnaces as complete installations—equipped with all controls, piping and wiring—ready to operate.

Salem-Brosius products—furnaces, forging manipulators, goggle valves, slag granulators, clay guns, charging machines, grab buckets, and special equipment—are engineered for peak performance at lowest cost, because we believe that satisfied customers are our best advertisements. Before you invest in any of these products, we suggest it will pay you to call in a Salem-Brosius engineer and let him study your problem and present a proposal.

SALEM-BROSIUS, INC.

CARNEGIE, PENNSYLVANIA

IN CANADA: SALEM ENGINEERING LTD. · 1525 BLOOR STREET WEST, TORONTO 9, ONTARIO



Controlled Quenching FOR BETTER PRODUCT

Battery of B & G Quench Tanks served by B & G Oil Cooling System illustrated above.

The above illustration typifies the quenching methods employed by modern metal fabricating plants to protect the quality of their products.

Here a battery of B & G *Hydro-Flo* Oil Coolers is employed to keep quench oil constantly at a predetermined temperature. By controlling quenching conditions, uniformity of product is assured.

B & G *Hydro-Flo* Self Contained Oil Coolers are complete packages... combining Coolers, Motors, Pumps, Strainers and all controls into single, integrated units. Fully automatic, they keep oil temperature at the desired degree through all stages of the quench.

Or, if you prefer, the component parts of a B & G *Hydro-Flo* Oil Cooling System may be purchased and assembled on the job. B & G Quench Tanks are also available... either in standard designs or built to your specifications.

Send for Catalog and Simplified Selection Manual.

Hydro-Flo®

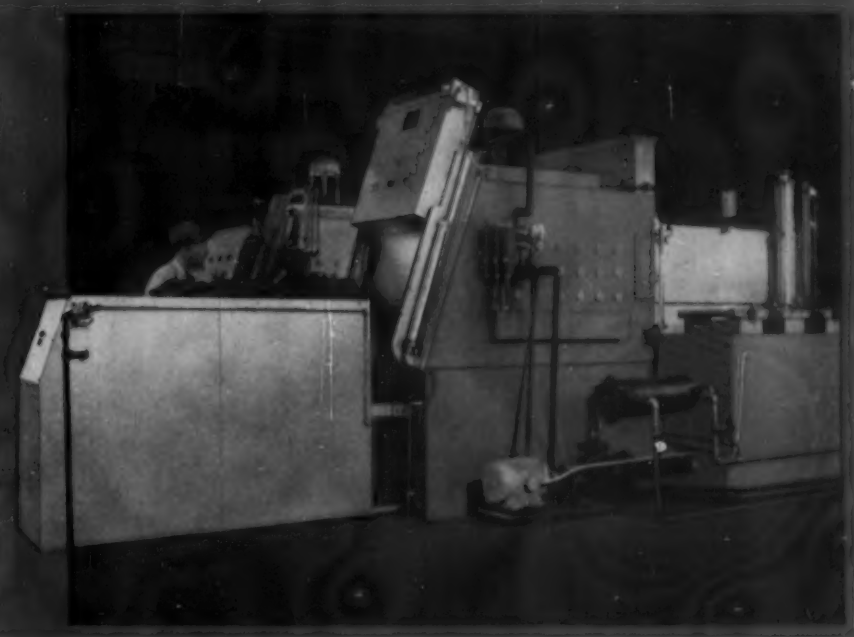
OIL QUENCHING SYSTEMS

BELL & GOSSETT COMPANY

Dept. DW-16, Morton Grove, Ill.

**Reg. U.S. Pat. Off.* *Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto*

another Pacific built furnace



for HEAT TREATING...

VERSATILITY OF THESE PACIFIC KARBO-MATIC FURNACES PAYS BIG DIVIDENDS AT ANGELUS STEEL TREATING CORP.!

The ability of a hardening furnace to handle a wide variety of work can mean the difference between its profitable use or a loss to commercial heat treating plants. That's why Angelus Steel Treating Corp. of Los Angeles recently installed their second Karbo-Matic!

This completely automatic Pacific Hardening Furnace can be used for carbo-nitriding, dry cyaniding or automatic hardening in a wide range of work sizes and different hardening jobs. Controls are simply set...work is placed on the loader rolls...and the furnace automatically carries the load through the complete, controlled heating and quenching cycle. No resetting of controls is necessary until a new and different production job is run. Clean, high-quality work is produced with speed and economy.

That's production-line performance!

These two Karbo-Matics, plus seven other different model Pacific Furnaces in the Angelus plant, provide a good example of the job-proven performance of Pacific-built equipment.

Write today for engineering assistance or complete data on a Pacific Furnace for your own particular needs!

© TRADE MARK

Licensed Eastern Manufacturer:
CASE HARDENING SERVICE CO.
Cleveland, Ohio

PACIFIC SCIENTIFIC CO.
Los Angeles
San Francisco
Seattle
Portland, Oregon
Arlington, Texas

Pacific ELECTRIC HEAT TREATING EQUIPMENT

PACIFIC SCIENTIFIC CO.
1424 Grande Vista Ave., Los Angeles, Calif.

☐ Please send me details on a Pacific Karbo-Matic Furnace.
☐ Information on the full line of Pacific Heat Treating Equipment.
☐ Please have a Pacific Representative call.

Name_____
Company_____
Address_____
City_____ State_____

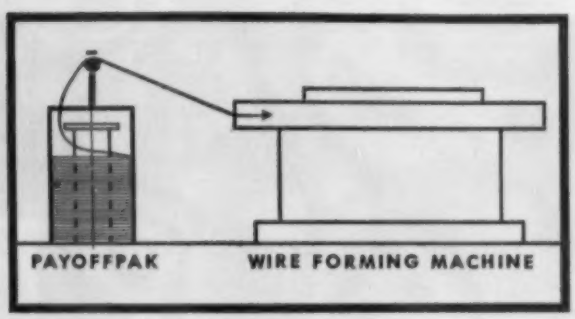
CUT Wire forming costs with CHASE® WIRE in new *Payoffpaks*!

Now, in this compact, easy-to-handle PAYOFFPAK you can get a continuous length of Chase copper alloy wire weighing 400 to 500 pounds!

This new Payoffpak puts an end to frequent set-up of wire-forming machines . . . means *more* continuous, economical operation, *less* costly down time!

You'll like the easy way this Payoffpak handles, the space-saving way it stores . . . and the way it protects the shining surface of Chase copper alloy wire from rough handling in transit and storage.

Ask your Chase Wholesaler or nearest Chase Warehouse about the new Payoffpak the next time you order copper alloy wire.



Chase®
BRASS & COPPER CO.

WATERBURY 20, CONNECTICUT • SUBSIDIARY OF KENNECOTT COPPER CORPORATION

The Nation's Headquarters for Brass & Copper

Albany†	Chicago	Detroit	Los Angeles	New York	St. Louis
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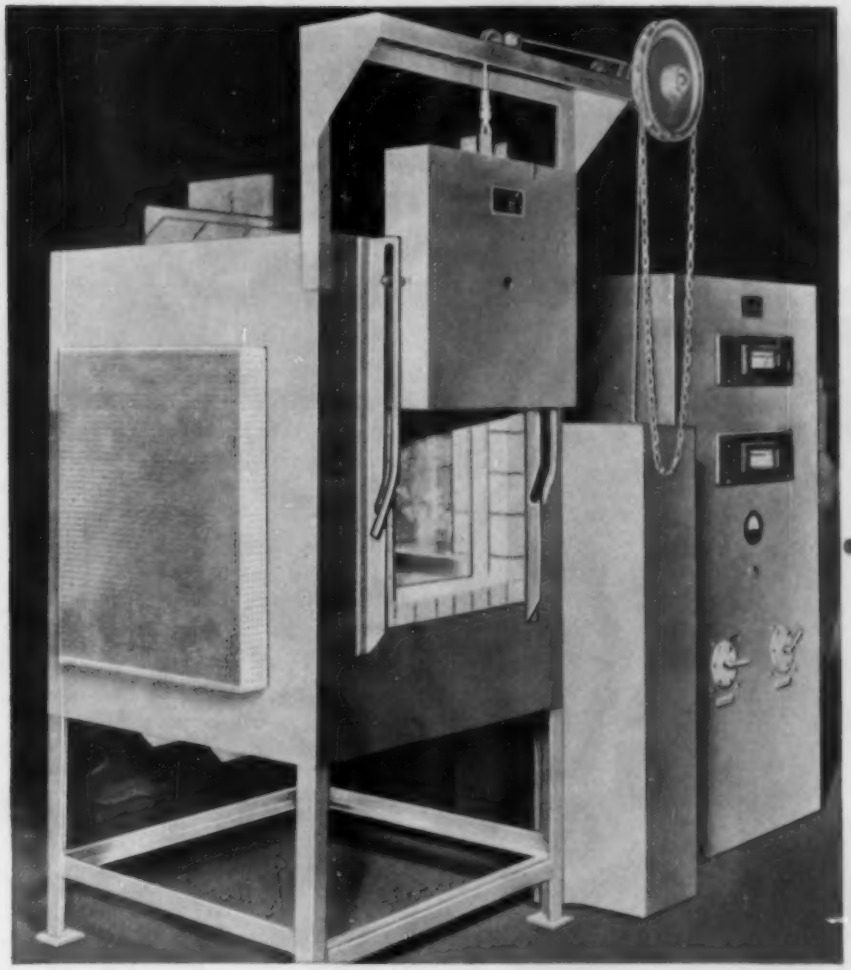
Baltimore	Cleveland	Houston	Minneapolis	Pittsburgh	Seattle
Boston	Dallas	Indianapolis	Newark	Providence	Waterbury
Charlotte†	Denver	Kansas City, Mo.	New Orleans	Rochester†	(†sales office only)



● **THIS HEAVY-DUTY HEAT TREATING FURNACE** operates up to 2700°F. with an atmosphere of air, and up to 2400°F. with hydrogen atmospheres. It employs GLOBAR® Heating Elements having a connected load of 34 KW. Designed and built by The Pereny Equipment Company, Columbus, Ohio.

GLOBAR® *Heating Elements selected for Heat Treating Furnace*

UNIFORM HIGH TEMPERATURES required for heat treating operations are assured, for extended service periods, when electric furnaces are equipped with GLOBAR® Silicon Carbide Heating Elements. GLOBAR elements can operate over a wide temperature range, to 2750°F.... permit accurately controlled heating at all times ... handle peak loads without danger of costly breakdowns.

In addition, GLOBAR non-metallic heating elements provide clean, silent and safe heat.

GLOBAR® *Heating Elements also give you:*

1. **LESS DOWNTIME**...no need to cool or unload when necessary to replace elements.
2. **SIMPLICITY OF FURNACE CONSTRUCTION**...compact, space-saving design.
3. **GREATER ECONOMY**...in both operation and maintenance.

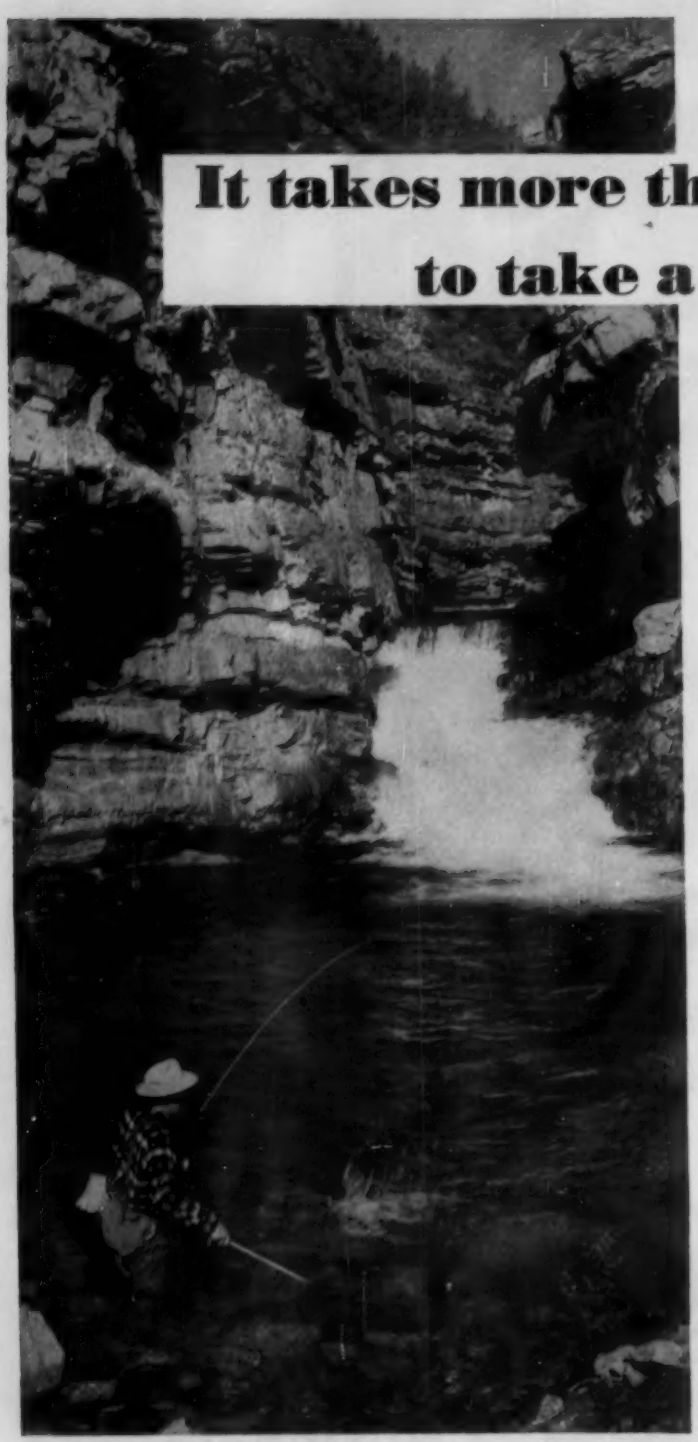
● **WHAT HEATING PROBLEMS** do *you* have that GLOBAR engineers can help you solve? Take advantage of their 30 years of experience working hand-in-hand with furnace manufacturers and users...get complete information on GLOBAR Heating Elements and how they can benefit you. Write The Carborundum Company, Dept. MP 87-515, Niagara Falls, New York. No obligation.

GLOBAR®

Heating Elements

by **CARBORUNDUM**

REGISTERED TRADE MARK



It takes more than a good fly to take a trout

Even the costliest fishing gear, the finest rod, the best reel and the prettiest fly can't assure catching a wily trout. It's the experience behind these accessories, that fills the creel.

There's no substitute for "Know-How" and that's particularly true in adapting metal treating chemicals to established production. It can't be gotten out of books, through black magic or out of a crystal ball. Only years of active contact, with actual manufacturing procedures, can be depended upon for satisfactory solutions of the metal protecting problems constantly confronting manufacturers.

ACP offers ideal products for removing and preventing rust on metal, chemicals to bond paint to steel, zinc, and aluminum, and pickling acid inhibitors. In addition, ACP furnishes a free service of an organization of technical experts with over 40 years' experience in solving metal preservation problems for the largest as well as the smallest operation.

Rely on service backed by experience. You are obligated in no way by consulting our technical staff.

Write or call for further information on ACP chemicals for metal protection.

Since 1914, Pioneering Research and Development in Metal Protection

CHEMICALS ACP PROCESSES

AMERICAN CHEMICAL PAINT COMPANY

CHEMICALS ACP PROCESSES

AMBLER, PENNA.

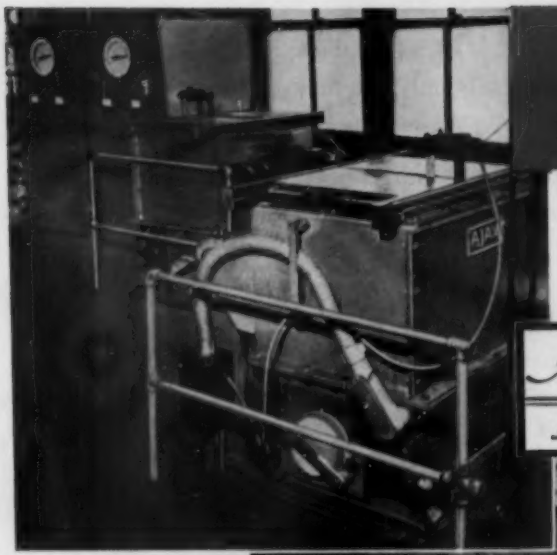
DETROIT, MICH. NILES, CALIF. WINDSOR, ONT.

AJAX INDUCTION FURNACES

mean Higher Quality Castings for...

Advance
TOOL & DIE CASTING COMPANY

Aluminum DIE CASTINGS *Zinc Base*

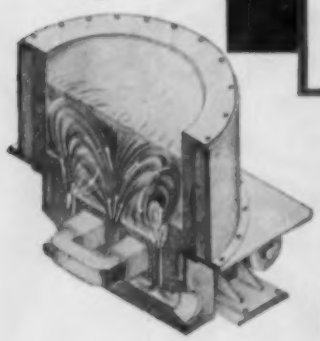


View above shows AJAX melting furnaces, with control cabinets in background.

View showing AJAX-TAMA-WYATT 20 kW, 60 cycle induction holding furnace supplying metal at exactly the right temperature to die casting machines.

The Furnace That Stirs Itself...

The sectional view below shows the twin-coil stirring action of the 100 kW, 60 cycle AJAX Induction Furnace. Heat induced in the secondary channels below is conveyed throughout the melt by electro-magnetic circulation, as shown by the arrows.



Inherent stirring action of these furnaces has proved most valuable to ADVANCE TOOL & DIE CASTING CO., Milwaukee, Wisc. In full operation for 18 months, the most important result of the use of these furnaces is higher quality die cast aluminum parts. The alloy is held in uniform solution, resulting in elimination of oxides, reducing hard spot trouble in secondary machining to a negligible factor. Temperature of the melt is held at 1170° F. through on-off control of the low power circuit. Working conditions are made more comfortable because of low heat losses. The units take up very little floor space.

AJAX ENGINEERING CORP., TRENTON 7, N.J.

AJAX-TAMA-WYATT = INDUCTION MELTING FURNACE

AJAX ELECTRO METALLURGICAL CORP., and Associated Companies
AJAX ELECTROTHERMIC CORP., Ajax Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., The Ajax Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax Wyatt Induction Furnaces for Melting

"Maybe we'd better scrap some of our ideas about scrap?"

DO YOU think of your scrap in terms of material costs only? Actually it's the time and labor that have been wasted upon it that is really costly.

Accepting an arbitrary rejection rate as inevitable, is expensive and usually unnecessary. The solution is often so simple it can be easily overlooked.

This may be the solution

Cracks in parts are one main cause for scrapping. When these cracks are not discovered until after machining or at final inspection, time spent in processing the parts is a dead loss!

Inspection with Magnaflux' Methods finds all cracks—from whatever cause—at any stage of manufacture. By finding cracks early you can correct the cause before parts are run in quantity. Result: almost no time or money is wasted on defective parts.

Inspection with Magnaflux is fast and cheap—saves many times its trifling cost. Ask to have a Magnaflux engineer show you how it can cut *your* costs—or write for new booklet on LOWER MANUFACTURING COST.

MAGNAFLUX

MAGNAFLUX CORPORATION

MAGNAFLUX CORPORATION
7346 West Lawrence Avenue • Chicago 31, Illinois
New York 36 • Pittsburgh 36 • Cleveland 15
Detroit 11 • Dallas 19 Los Angeles 38

one must set the example

. . . and with high speed steel it's REX

It's a real satisfaction when you set the example by what you make . . . when it becomes a *standard for comparison*. That's why Crucible is proud to have kept REX high speed steel tops in its class for so many years.

But don't take our word for REX's superiority. Try it on your own work. Compare its structure, finish, hardenability, carbide distribution and general uniformity. You'll see for yourself why it's the *standard* wherever high speed steels are used.

Remember, REX is made only by Crucible. So call for REX at your nearby Crucible warehouse, or for quick mill delivery — *Crucible Steel Company of America, Henry W. Oliver Building, Pittsburgh 22, Pa.*

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Small diameter Inconel rod locks tray segments in position; eliminates structural welds and permits tray to expand and contract without undue stress. This Inconel tray is made by Misco Fabricators, Inc., 1999 Guoin St., Detroit 7.

Misco uses Inconel to triple life of gas carburizing fixtures

The tray you're looking at carries 30 pounds of odd-shaped baffles through 1650°F. . . . in a continuous furnace.

An oil quench follows . . . the entire heating and cooling cycle taking 11 hours.

At one time, fixtures were made of an alloy steel . . . and lasted only *three* months before failure from cracking and breaking.

Then Misco Fabricators, Detroit, switched to Inconel®. . . and the service life of the equipment was extended to *nine* months.

A 200 per cent improvement! But expected. For Inconel withstands severe thermal shock without spalling . . . sudden cooling without cracking. And has excellent resistance to reducing, carburizing or nitriding atmospheres.

By using Inconel fabricated equipment, the heat treater gets light, but rugged, fixtures . . . designed for his specific needs. And he gets strength and corrosion resistance at high temperatures.

So, if heat isn't treating *your* equipment well you'll probably save your disposition and money by writing for our booklet "Keep Operating Costs Down When Temperatures Go Up."

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N. Y.

Inconel

INCO TRADE MARK **Nickel Alloys**

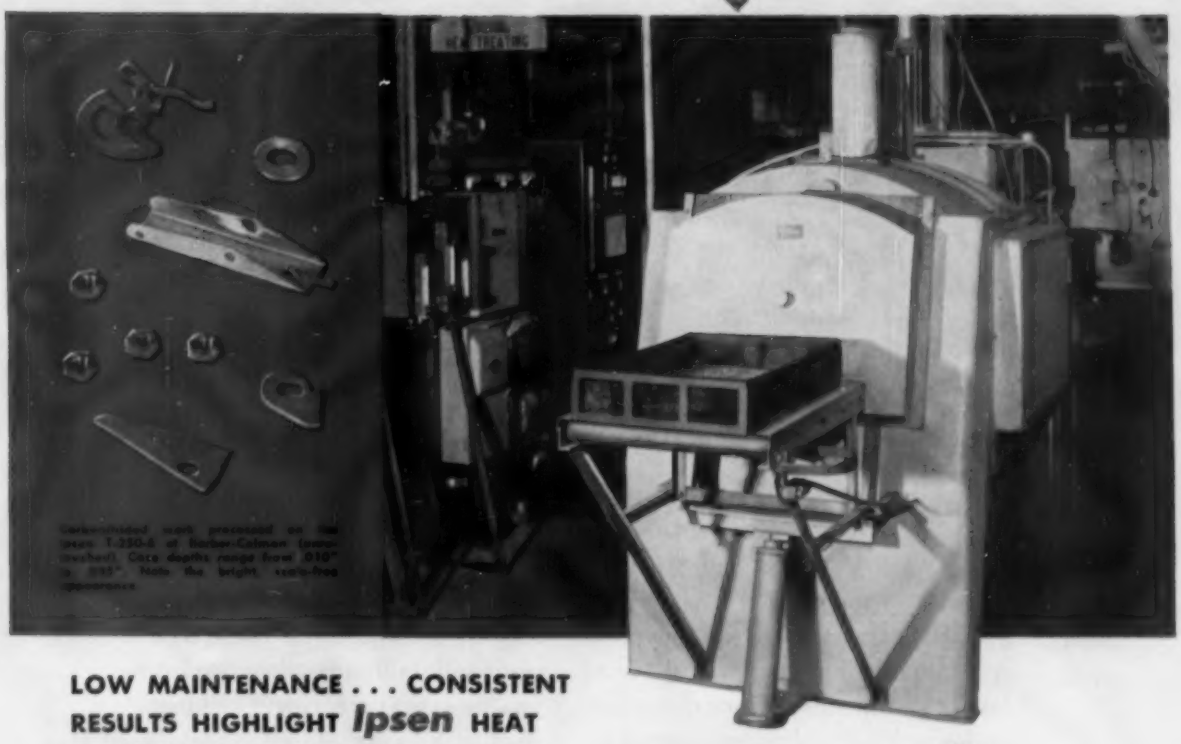
. . . for long life at high temperatures

MAINTENANCE COSTS

less than 3¢ per hour

ON THIS IPSEN INSTALLATION

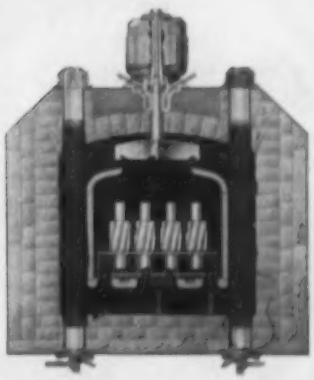
at BARBER-COLMAN



LOW MAINTENANCE . . . CONSISTENT RESULTS HIGHLIGHT *Ipsen* HEAT TREATING INSTALLATION AT BARBER-COLMAN

Total maintenance expense . . . $395.56. Total hours of operation . . . 13,200. Type of work . . . 65% bright carbonitriding, 20% bright carburizing, all other, 15%. ***Less than 3 cents per hour for maintenance.*** That's the report from the Barber-Colman Heat Treating Department on this Ipsen T-250-E Furnace since its installation.

Now . . . Ipsen's latest 100% Forced Convection design cuts low maintenance costs even more.



GET THE FACTS—See for yourself how Ipsen "Controlled-Atmosphere" Furnaces can cut your heat treating costs. We'll be glad to send you all the details.

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC., 723 So. Main St., Rockford, Illinois

Controlled Atmosphere Heat Treating Units

Controlled Atmosphere Tempering Units

Automatic Washers

Dowtronic and Carbotronic Controllers

Atmosphere Generators

IX

This is the ninth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

The Effect of Nickel in Alloy Steels

Each element in an alloy steel has its own particular job to do, and each is included with a special purpose in mind. What are some of the reasons, say, for using nickel, chromium, molybdenum, vanadium, and other components that appear in the various analyses? The elements in any alloy steel work both individually and as a team. What does each one do? In this and subsequent discussions we shall try to answer these questions, beginning with nickel, one of the fundamental alloying elements.

Nickel increases toughness and resistance to impact, particularly at low temperatures; lessens distortion in quenching; improves corrosion-resistance. It lowers the critical temperatures of steel and widens the temperature range for successful heat-treatment.

Nickel steels are particularly suitable for case-hardened parts, such as aircraft-engine gears and roller bearings. Such steels provide strong, tough, wear-resistant cases and also ductile core properties.

Advantages imparted by nickel are not restricted to quenched-and-tempered steels. Nickel often permits given strength levels to be obtained at considerably lower carbon contents, thereby markedly increasing toughness, plasticity, and fatigue-resistance. Nickel steels are therefore highly suitable for applications where liquid quenching is not employed, such as high-strength structural steels used in the as-rolled condition or heavy forgings not adapted to quenching. Products of this nature must develop superior properties after nothing more severe than air-quenching treatments.

If you would like to know more about nickel steels, or need information about other types of alloy steels, please feel free to consult with Bethlehem's metallurgists. These technicians will gladly advise you regarding analyses, heat-treating, machinability, etc. You are invited to make use of their services whenever you need assistance.

And may we remind you, too, that Bethlehem makes all AISI standard alloy steels, as well as special-analysis steels and the full range of carbon grades. We are always in a position to meet your needs promptly and fully.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

The Bendix* Martempering Story...

*Bendix Products Division
Bendix Aviation Corporation
Automobile, Aviation, Marine and
Industrial Products, South Bend, Ind.

...with Park

NU-SAL NEUTRAL SALT

(Melting point 1230°F. / working range 1300-1650°F.)

and

THERMO-QUENCH SALT

(Melting point 290°F. / working range 325-1100°F.)

PART

Products are aircraft landing gear steel components, including forgings, arc and flash welded assemblies, basically tubular with complex lugs.

PROBLEMS

1. Eliminate decarburization and scaling.
2. Reduce distortion.
3. Reduce residual stresses resulting from heat treatments.

SOLUTION

Using an immersed electrode-type furnace 96" deep, these complex parts were austenitized in Park Chemical's Nu-Sal neutral salt at 1550°F. for 45 minutes. Previous method used 1½ hours. Quench at 400°F. is in Park Chemical's Thermo Quench Salt. Steels used are AMS 6324, AMS 6415 and AMS 6427.

Salt baths offer tremendous advantages over conventional heat treating methods. As much as 80% of all heat treating can be done in salt. Speedy handling and small floor space cuts costs. Quality is increased by eliminating quench cracks, scaling and decarb, while improving toughness and ductility.

Sixth in a series of advertisements describing Park processes on the job

• Liquid and Solid Carburizers • Cyanide, Neutral, and High Speed Steel Salts • Coke • Lead Pot Carbon • Charcoal • No Carb • Carbon Preventer • Quenching and Tempering Oils • Drawing Salts • Metal Cleaners • Kold-Grip Polishing Wheel Cement

Park

PARK CHEMICAL CO.

8074 Military Avenue • Detroit 4, Michigan

Send Free Bulletin on Neutral Salt Baths

Name _____ Position _____

Company _____

Address _____

City _____ State _____

MULTIMET alloy wraps are joined by welding in the fabrication of aircraft cabin heaters.

MULTIMET Alloy Wraps Absorb the Heat from a 3500 deg. F Flame

MULTIMET alloy wraps are used to absorb the intense heat from burning aviation gasoline in aircraft cabin heaters. The spirally wrapped alloy sheet transfers the combustion heat to fresh ventilating air. Very thin sheet — only 0.025 in. thick—does an excellent job here despite the high metal temperatures and the oxidizing conditions.

Rigorous 1,000-hr. tests were conducted before MULTIMET alloy was selected for this job. It has now been the standard material for seven years. The excellent high-temperature properties of the alloy made it possible for designers to use thin sections, which insure a light, compact heater, with excellent heat-transfer efficiency.

MULTIMET alloy is one of many HAYNES high-temperature alloys for economical use over a wide range of operating conditions. It has given good service for engine manifolds, turbine blading, heat-treating equipment and many aircraft components. For a copy of a booklet describing HAYNES high-temperature alloys, and for prices and sizes of MULTIMET alloy, get in touch with the nearest Haynes Stellite Company office.

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

General Offices and Works, Kokomo, Indiana

Sales Offices

Chicago · Cleveland · Detroit · Houston · Los Angeles · New York · San Francisco · Tulsa

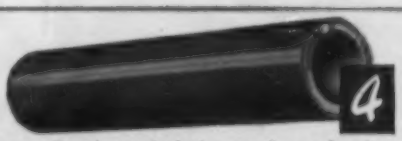
"Haynes" and "Multimet" are registered trade-marks of Union Carbide and Carbon Corporation.

7 WAYS to SAVE MONEY with TOCCO* Induction Hardening

Cost was reduced 94% when heat-treatment of this corn-harvester part was changed from carburizing to TOCCO-hardening, 9½c saved on every piece — $4750 on each 50,000 piece batch, plus an hourly production increase from 120 to 300 pieces per hour.

$375 per day! When Salisbury Axle switched to TOCCO-hardening axle shafts. Less machining—30 seconds instead of 2 minutes—means lower tool cost. Also production zoomed from 50 to 120 per hour. TOCCO hardened shafts have 200% greater torsional life.

Kearney & Trecker Corp. reduced the cost of hardening this milling machine part from $1.57 to 10c apiece. In addition TOCCO made possible a switch from alloy to S.A.E. 1045 steel—saving another 11c per piece in material cost. Kearney & Trecker hardens 140 different parts on one TOCCO unit.



Thompson Products Ltd. boosted production of these automotive wrist pins from 500 to 1200 per hour when they switched to TOCCO-hardening. Costs fell from $5.45 to $3.25 per hundred parts—a savings of 2c per pin, $26.40 per production hour.

Mechanics Universal Joint Division of Borg-Warner reports a 69% savings in the hardening of stub ends for propeller shafts. TOCCO also upped production from 35 to 112 parts per hour—over three times as fast as conventional heating methods.

Lima-Hamilton Corporation adopted TOCCO for hardening this shifting lever. Results: a savings of 4c per piece—$25 per production hour. TOCCO costs only 17% of former heating method. This is only 1 of 139 parts TOCCO-hardened by Lima-Hamilton Corp. All show savings over usual heating methods.

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Assures high and uniform hardness.

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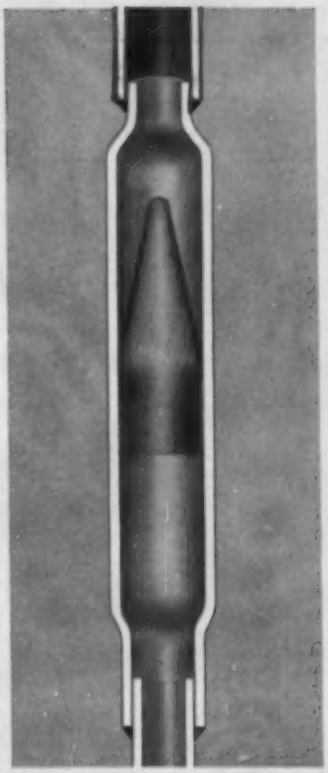
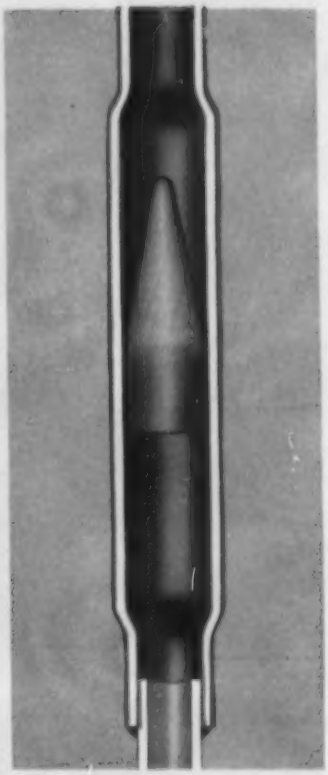


Problem: Because refrigeration systems can be quickly ruined by dirt particles which lodge in capillary tubes, most systems use a separate strainer assembly, as shown above. The two extra solder joints used to install the strainer assembly give rise to an even greater problem—leakage. Expensive hand assembly methods also frequently introduce dirt into the system.



Solution: New Bundy design actually makes strainer an integral part of condenser coil. The coil end is expanded to receive the strainer or filter and then swaged down to capillary size. This ingenious design eliminated one solder joint with its consequent risk of leakage or dirt inclusions; resulted in a cost savings of 50% to the customer.

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In Defense of Metal

(Since Such Seems to Be Needed)

We present in the first article in this issue of *Metal Progress* a brief digest of the voluminous testimony before the British court of inquiry into the cause of the two disasters to "Comet" jet air liners in January and April of 1954, taking 56 people to their death. Such an opportunity is rather rare. Disasters are seldom given much publicity. Usually too many people, corporations or governmental bureaus wish to avoid any responsibility – moral or financial – to release much information.

As to the Comets, the Royal Aircraft Establishment had conducted extensive studies using much unconventional equipment to get at the root of the trouble. This work had caused a test ship to "explode"; one whole panel of fuselage skin ripped open, the tear starting from small fatigue cracks (identified by their porcelanic fracture) at rivet holes where a hatchway frame was attached. Subsequently, fragments from one of the wrecked planes, dredged up from the Mediterranean, were found to have a similar tear in the cabin skin, the fracture apparently triggered by a small fatigue crack at a rivet hole where a window frame (a "reinforcement" – God save the mark!) was attached.

Throughout the news accounts which have crossed the editorial desk the theme is repeated that the cause was "metal fatigue". A writer in the *Saturday Evening Post* quotes an unnamed "expert" as saying, "Aeronautics did not let us down; metallurgy did." If this expert was corporeal and not imaginary, it's a certainty he was not a metallurgist!

For look what the evidence shows:

They made a fuselage of aluminum alloy whose specified minimum tensile strength was 60,500 psi. It contained several doors and windows and a lot of rivet holes. Under test, *ex post facto*, the maximum service stress was found to be 45,700 lb., which was reached two or three times in each high-altitude flight. Riveted cylinders failed after about 2000 loadings to this peak stress – 75% of the guaranteed strength of the aluminum sheet. Then when the ship, with precious human cargo, was lost before it had made 2000 pressurized flights, "The metal failed by fatigue!"

It may be reassuring to future passengers on stratospheric cruisers to learn that the British aircraft builders "propose to use thicker-gage materials in the pressure cabin area and to strengthen and redesign windows and cut-outs, and thus lower the general stress level at which local stress concentrations – either at rivet and bolt holes, or such as may occur by reason of cracks caused accidentally during manufacture or subsequently – will not constitute a danger." (Quotes are from Mr. Bishop, author of our article.) It would be more reassuring to the Editor of *Metal Progress* if they would go ahead and *eliminate* those rivet holes around window frames which proved so deadly. E. E. T.

Wonder Metal Re-Viewed

When titanium emerged from the laboratory to limited production seven years ago, it was hailed in the popular press as the "wonder metal" destined to replace large amounts of aluminum alloys and stainless steel. Sample orders came in from all sides and many engineering hours were spent trying to fit its properties to existing and planned designs. Today, seven years later, it is used entirely for military applications – primarily

aircraft, but also for some ordnance and marine parts. No use in civilian consumption has yet been reported. The major deterrent is price. A minor difficulty is that some lots have had unpredictable mechanical properties and erratic fabrication behavior. Also some of the commercial alloys are not as corrosion-proof as expected.

Mallory-Sharon Titanium Corp. recently held a "Titanium Day" to display its new melting facilities. Incidentally we searched for an answer to the questions: "Why does titanium cost so much and what can be done about it?" Titanium sponge (where we start) now costs $3.95 per lb. It is blended with the necessary alloying elements, compressed into a coherent, rectangular slug and these are welded together end to end to form a consumable electrode of proper length for the vacuum melting furnace.

After melting in vacuum, and then remelting, the ingots are valued at approximately $9 per lb. They must be machined to remove surface imperfections, forged, and cut into sheet bars. The sheet bars are then hot rolled into finished sheets. (Very little cold rolling is done on titanium alloys.) In sheet form its value has been redoubled and it sells for $15 to $25 per lb. – 40 to 50 times as much as stainless steel or aluminum alloy sheet.

Nevertheless, the jet aircraft industry has justified the use of titanium alloys primarily by weight savings. Some uses may also be found by the Navy and by Army ordnance – at any rate, it is reported that the total capacity now planned will make about 28,000 tons of ingot per year by 1960. (Present *consumption* is on the order of 5 tons per day, or at the rate of 1500 tons per yr.) An interesting aside to the usage in aircraft is the statement by John Goldthwaite of Allison Div. of General Motors Corp. that for every pound of metal in a jet engine, four pounds of raw material must be purchased.

It might sound easy to cut costs when you start with such a high figure as $15 per lb. for simply melting and rolling, but too much of the cost is due to the quality requirements and the attendant heavy scrap loss (upwards of 33%). Scrap is now practically worthless, since it costs more to prepare it for melting than its equivalent weight of sponge. It can be fed into the charge only in the form of turnings or chips, and the cleaning, segregation, and machining are expensive operations. Mallory-Sharon recognizes the fact that eventually scrap *must* be recirculated to reduce costs. All heats made now contain some scrap, and Mallory-Sharon is now adding about 22% scrap to its raw material (sponge) in an attempt to develop an inexpensive technique for recovery.

Double melting in vacuum furnaces sounds like an unnecessarily expensive operation, but the second melting improves quality – more hydrogen has been sucked off. It also saves money; the ingot from the first melt is very rough and about 1½ in. would have to be machined from the surface to reach sound metal, whereas after remelting the ingot is much smoother so less than ⅛ in. must be machined off. The saving in scrap more than offsets the cost of remelting the first-run ingot. An alternative might be the scheme devised by Westinghouse engineers, who have eliminated the machining of similar double-melted ingots of hafnium by surface fusion. They simply rotate the ingot on a lathe fixture in an inert gas atmosphere and weld a continuous bead over the periphery with a nonconsumable electrode. Their recovery from raw material to ingot suitable for rolling is 99.8%.

In rolling a sheet of titanium one of the major costs is chemical analysis; hydrogen must be determined after each heating and cleaning operation. The cost of these six to eight analyses alone is between $60 and $80 per *sheet*. Some other expensive operations are the more than 30 handlings in process; the use of two sheets of mild steel to sandwich the titanium during rolling (the steel sheets are subsequently scrapped); and the inspections after each operation.

If there were a demand for commercial quality, in addition to aircraft quality titanium; and if production increases several fold so special mill equipment can be installed and kept busy; and if some processing problems can be licked; and if sponge price is reduced to $1 per lb.; and if scrap can be used economically; then titanium sheet may sell for as little as $5 per lb. Pretty "iffy"; a more realistic guess might be that if sheet production can increase by a factor of 10 – as is predicted by 1960 – the price of sheet will be halved – say to $10 per lb.

At any rate, do you have any use for this "wonder metal"? J. T.

Correction

The micrographs in Fig. 3, p. 98 of *Metal Progress* for February 1955 were mistakenly identified during editing. It is hoped that few readers were misled because this transposition is so obvious.

Fatigue and the Comet Disasters

*By TOM BISHOP**

The British inquiry into the cause of disasters to jet-propelled air liners will doubtless remain a classic for all investigators of structural failures. It appears probable that, at a high altitude, a tiny fatigue crack initiated catastrophic failure of the cabin wall and the pressurized cabin literally exploded.

After the crashes of the British de Havilland jet-liners near Elba on Jan. 10, 1954 and near Naples on April 8, 1954, the fleet of these passenger aircraft nicknamed the Comets was grounded. These accidents triggered off what is probably the most exhaustive and costly series of tests ever undertaken to investigate a failure. A public inquiry was started in London in October 1954 which lasted 22 days, evidence being heard from 68 witnesses, and 145 exhibits shown. Excluding the report on the investigations at the Royal Aircraft Establishment at Farnborough, England, directed by Sir Arnold Hall, the evidence to the Court covered 1600 pages of transcript, representing over 800,000 words. In addition, Sir Arnold Hall's report from the Royal Aircraft Establishment, presented at the opening of the inquiry, contained over 120,000 words and 285 illustrations; it was 4 in. thick and weighed 10¼ lb. An attempt is made here to summarize briefly this massive documentation, the engineering and metallurgical tests carried out to determine the cause of the accidents, and the findings of the marathon investigation, which were released in February of this year. Prior to that time publicists in England were prevented from analyzing the case or reporting in anything but general terms, it being inadvisable to discuss cases under judicial inquiry, as this one was.

When the last crash occurred just off shore near Naples, the wreckage retrieved of the previous accident from shallow water near Elba was only just beginning to accumulate, having been spotted by underwater television. No deductions could yet be drawn from it. Early attempts were therefore made to assess the probable causes in the light of general evidence. In particular, it was noted that both accidents had occurred during initial climb and at heights of 30,000 to 35,000 ft. It was precisely under these conditions (where maximum stresses would exist in the

*Editor, *Metal Treatment and Drop Forging*, London, England; British correspondent for *Metal Progress*.

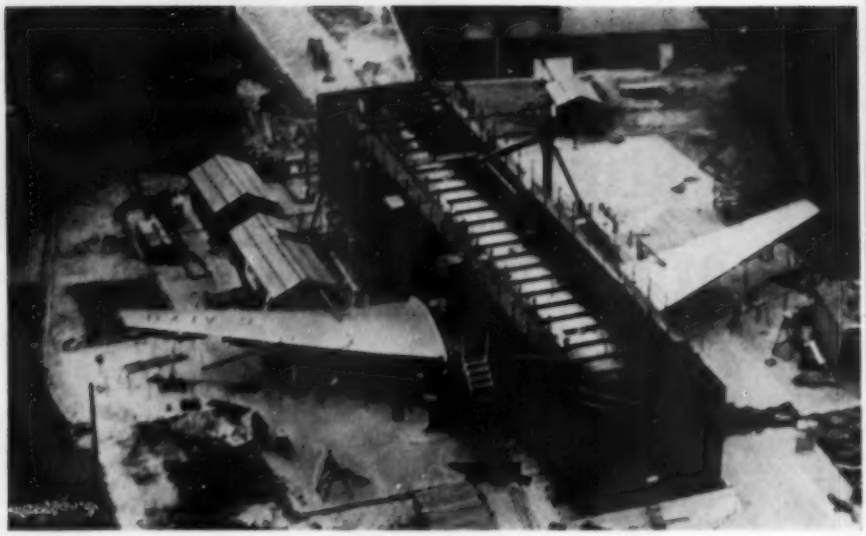

Fig. 1 – The Wings of the Comet Jet Liner G-ALYU ("Yoke Uncle") Stick Out Through Water-Tight Seals From the Tank in Which the Fuselage Was Fatigue Tested to Destruction by Pulsating Internal Pressure. This and other photos are from the British Ministry of Supply. Crown copyright reserved

walls of the pressure cabin) that fatigue failure would be expected to occur if the structure had been underdesigned or if unprovided for and localized stress raisers existed. Fatigue failure of the pressurized cabin structure was therefore tentatively listed as a possibility.

Other factors were also taken into consideration by the investigators at Farnborough. Comets had been operating with pressures in the cabin greater than had hitherto been in general use for civil aircraft. Furthermore, owing to its size, the pressure cabin had not been tested as a complete unit, although the designers and builders had done much testing in sections. Finally, there might be some unpredictable interaction within the cabin structure between gust loads and pressure loads which could only be discovered by tests with apparatus of a kind that was not yet in existence.

The Farnborough Test

A new type of test was therefore devised and special apparatus built wherein the fuselage was filled with water and also entirely submerged in a large tank of water (Fig. 1). A pumping system was arranged so that internal cabin pressure rose and fell realistically. For these tests a complete airplane was used, the wings remaining in position. Only their roots were submerged with the fuselage; the most of the wings projected through the sides of the water tank. A flexible seal held back the water and allowed the necessary freedom for articulation. The equivalents of up-and-down gust loads were also applied to the wings outside the tank by hydraulic rams.

The test rig is believed to be the first of its kind to apply and cycle the air loads on the wing simultaneously with the pressure loads on the cabin. As remarked above, the rig comprised a 200,000-gal. water tank 112 ft. long by 20 ft. wide by 16 ft. high. The complete aircraft G-ALYU (or "Yoke Uncle") was wheeled into the rig when the latter was about half built. Working

Fig. 2 – Long Tear in Front Fuselage of Yoke Uncle Starting From Fatigue Failure at Rivet Hole Attaching Reinforcement Around the Forward Escape Hatch

night and day, the rig was designed and constructed in about six weeks. The fuselage was appropriately ballasted to give the correct loading conditions.

This Comet G-ALYU had already flown for 3500 hr. – about the same length of time as the ill-fated one which crashed into the Mediterranean off Elba. After pulsating tests giving a total life equivalent to about 2¾ times the former life in flying, a crack suddenly opened and a large piece of the pressure cabin wall was pushed out (Fig. 2). The corresponding damage to a cabin filled with compressed air would, in all probability, have amounted to widespread destruction due to the expansibility of the gas.

The first conclusion to be drawn from this experiment was that "Yoke Uncle" (G-ALYU) would, had it continued to fly, have met with disaster after about 9000 hr. of flying, through weakness of the pressure cabin wall. Corresponding deductions concerning the two Comets which went down near Elba and Naples were less positive, for such fundamental reasons as that the fatigue lives of nominally identical structures vary considerably. However, experience regarding such variation in life of rather simple mechanisms subjected to alternating or pulsating loads indicated that fatigue failure of both these ill-fated aircraft was definitely possible.

The water-tank test was also applicable to wing fatigue since, so far as was known, the special arrangements for loading the pressure cabin did not invalidate the test for the wings. A serious crack developed at the wheel-well at about 5500 hr. total, and it was considered that if the test had continued without repairs, the crack would have become catastrophic. Structural failure in this region, however, did not appear in the Elba wreckage recovered.

Test Loadings

The main loads imposed during the tests at Farnborough were (*a*) cabin pressure, (*b*) steady loads in level flight and (*c*) up-and-down gust loads on the wings. The cabin pressure was simply a cycle of differential pressure rising from zero to 8.25 psi. and falling again to zero, such as occurs in a climb to 40,000 ft. and return to ground level. Superimposed gust loads on the wings corresponded to alternate up-and-down gusts of 10 ft. per sec.

In this life-sized test under alternating loads the first damage occurred when a portion of the cabin wall, about 8 × 3 ft. in size, was forced outwards. This portion included the forward escape hatch, with its window insert, on the port side. On later examination a small fatigue crack in the skin was discovered at a rivet hole in the lower rear corner of the escape hatch frame. It was considered that this was the start of the failure which progressed rapidly. Even later examination revealed another crack about 1¼ in. long in the cabin skin at the upper rear corner of the first window forward of the wing rear spar on the port side.

Metallurgical Examination

The fractures in the fuselage of the test Comet G-ALYU after a total of 3057 pressurized "flight cycles" in the water tank were examined most carefully at Farnborough. A piece of the skin from the port side fuselage, containing one side of the longitudinal fracture produced in the fatigue test was examined for evidence of fatigue. This portion of 20-gage (0.036 in.) D.T.D. 546 clad aluminum sheet* was about 7 ft. 6 in. long and had an average width of about 8 in. The important region was the inner surface at the lower

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*Extract From D.T.D. 546 B (Superseding Specification No. D.T.D. 546 A), April, 1946:

Chemical Composition

2.1 The chemical composition of the alloy comprising the core of the sheets and coils shall be: copper, not less than 3.5 nor more than 4.8%; iron, not more than 1.0%; silicon, not more than 1.5%; magnesium, not more than 0.6%; manganese, not more than 1.2%; titanium, not more than 0.3%, and aluminum, the remainder.

2.2 The composition of the coating shall be aluminum, not less than 99.7%.

Mechanical Tests

The mechanical properties of the test pieces machined from the samples selected and prepared as specified in Clause 7 must comply with the following tests:

Tensile Test – 0.1% proof stress [applicable only to sheets and coils thicker than 25 standard wire gage (0.020 in.)] not less than 21 tons per sq.in. (47,000 psi.); ultimate tensile stress, not less than 27 tons per sq. in. (60,500 psi.); for sheets and coils thicker than 12 S.W.G. (0.104 in.), elongation not less than 8%.

Single Bend Test (applicable only to sheets and coils 12 S.W.G. and thinner) – The test pieces must withstand without cracking being bent as specified in Clause 6.4 over a radius equal to five times the nominal thickness of the sheet or coil.

[Editor's Addition: The corresponding American alloy is 24 S-T 4, nominal composition 4.5% Cu, 0.6% Mn, 1.5% Mg. In Alclad 1/16-in. sheet the tensile strength is 58,000 psi. min., the yield strength is 37,000 psi. min., and elongation in 2 in. is 11% min. Endurance strength for 500 million cycles in reverse bending of bare 24 S-T 4 is 20,000 psi. – see *Metal Progress* Data Sheet No. 521.]

part of the escape hatch. As shown in Fig. 3, fracture had occurred through two countersunk rivet holes at the rear edge of the hatch, and another at the forward edge. The fracture at the rear side of the hole was consistent with fairly rapid fatigue and similar in form and texture to other fractures produced in the laboratory with fresh D.T.D. 546 sheet in test specimens, containing a drilled hole, when loaded axially in cycles from zero to a load sufficient to break them after 800 to 4000 loadings.

On the forward side of the rivet hole, the angle of fracture was off normal and gradually changed to that consistent with tensile failure, approximately 45° to the direction of maximum stress. This again indicated rapid failure that most probably commenced after the start of a fatigue crack on the rear side of the hole. Under the microscope, small specks of green algae were present in the fracture along a hollow portion 0.07 in. long, suggesting that this was probably the length of the fatigue crack before the very rapid tensile tearing commenced. The surface of the countersink on the rear side was rough and blackened due, most probably, to a combination of attrition and corrosion. Such roughening would also lower the endurance of the metal appreciably.

Of the other two rivet holes, the fractures at the rear and forward edges of one were more consistent with tensile failure, but in the other, a tiny area of fatigue fracture was present at rear and forward edges, leading into a coarser, fractured surface more typical of tensile failure.

The total equivalent life, including actual flying of the aircraft tested, was 3057 pressurized flights; 439 unpressurized flights; six proving tests to 11 psi. and 9000 hr. total flying.

The pressure cabin of "Yoke Uncle" was repaired at this stage, a complete new piece of structure being fitted into place at the region shown in Fig. 2. Strain gages were then attached all around the window corners. The results for the worst situations, given for the component loadings separately, were as follows:

Loading	Stress
8.25 psi. pressure (by strain gage)	35,100 psi.
Plus extrapolation to edge	8,000
Difference between steady loads in level flight and aircraft on ground	650
Gust of 10 ft. per sec.	1,950
Total, maximum	45,700 psi.

Thus a peak stress of 45,700 psi. was deduced, a stress which, in practice, is reached two or three times per flight. For the actual material (D.T.D. 546) the estimated static strength is about 65,000 psi., so that the peak working stress was 70% of the ultimate! Furthermore, rivet holes in the stress field cause localized increases in this measured stress over regions too small for measurement by strain gages.

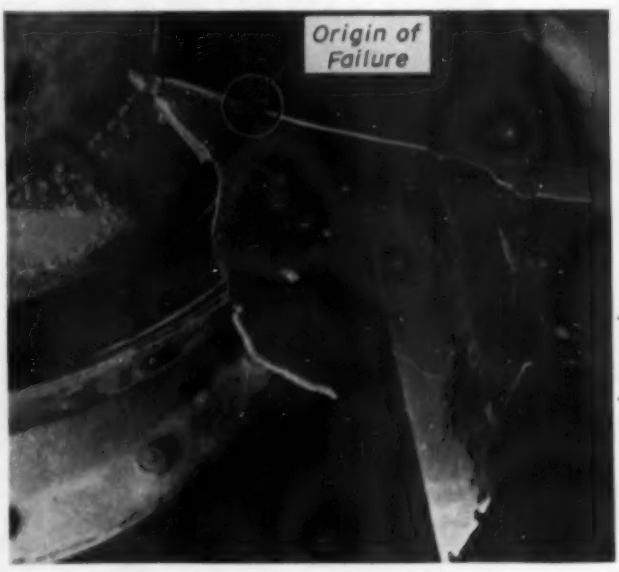
While these tests were being made on the ground two other Comets had been converted into flying laboratories. One, G-ALAV or "Able Victor" was plastered inside and out with strain gages, loaded with recording instruments attended by a score of observers, and flown daily to compare actual and computed stresses for various flight conditions. A third, G-ALYS or "Yoke Sugar" was used for fueling tests to determine the possibility that the disasters might have been caused by gasoline explosions, a hypothesis noted below.

Fatigue Tests on D.T.D. 546 Material

Fatigue tests were made on D.T.D. 546 material in a Haigh fatigue machine, and on cylinders loaded cyclically with internal pressure.

The Haigh machine varied the stress in a drilled specimen from zero to a maximum. The specimen was 0.5 in. wide, 0.035 in. thick and the hole 0.012 in. in diameter. The theoretical stress concentration factor was 2.42. The results

Fig. 3 – Close-Up of Fuselage Skin at Bottom Rear Corner of Escape Hatch, After Failure Shown in Fig. 2, Viewed From Outside



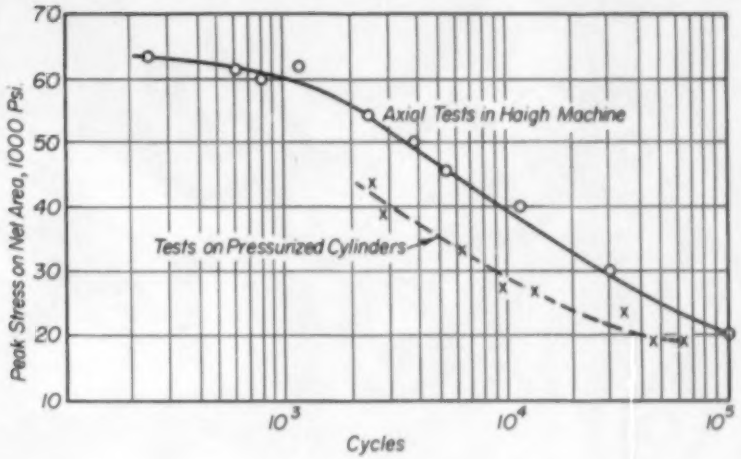


Fig. 4 – Fatigue Tests on D.T.D. 546 Alclad. Axial tests on drilled specimen (stress concentration Factor: 2.42). 44-in. cylinders had two longitudinal riveted joints

obtained are shown as the full line in the accompanying graph, Fig. 4, plotted by the author.

Tests on large hollow cylinders, 44 in. in diameter, were caried out by an outside firm. The cylinder walls were 0.036 in. thick; they had a riveted lap joint along one side and a riveted butt along the other. Rivets were ⅛ in. diameter with countersunk heads. The cylinders were loaded cyclically with internal pressure which varied from zero to a maximum. Results of these tests are given in the dashed curve.

Opinions From the Farnborough Report

The Farnborough Report (portions of which formed part of the evidence before the court) contains an outline of the investigation and states the opinion which the Royal Aircraft Establishment's staff had formed as to the cause of the accident:

"We have formed the opinion that the accident at Elba was caused by structural failure of the pressure cabin, brought about by fatigue. We reach this opinion for the following reasons:

"1. The low fatigue resistance of the cabin has been demonstrated by the test described and the test result is interpretable as meaning that there was, at the age of the Elba airplane, a definite risk of fatigue failure occurring.

"2. The cabin was the first part of the airplane to fail in the Elba accident.

"3. The wreckage [assembled as in Fig. 5] indicates that the failure in the cabin was of the same basic type as that produced in the fatigue test. [See Fig. 6]

"4. This explanation seems to us to be consistent with all the circumstantial evidence.

"5. The only other defects found in the airplane were not concerned at Elba, as demonstrated by the wreckage.

"Owing to the absence of wreckage, we are unable to form a definite opinion on the cause of the accident near Naples, but we draw attention to the fact that the explanation offered above for the accident at Elba appears to be applicable to that at Naples."

(It might be added that the medical evidence as to the state of the bodies recovered was consistent with the conclusion thus reached.)

Other defects mentioned in ¶5 above were (*a*) the relatively low resistance of the wing to fatigue; (*b*) the possibility of gas from the fuel tank venting system entering the trailing edge area of the wing near the jet pipe shrouds; and (*c*) risk of internal damage during refueling to the outer wing tanks under conditions which, though abnormal, may sometimes have occurred in practice. (As noted above, this possibility had been exhaustively studied during flights with G-ALYS, "Yoke Sugar".)

Lord Cohen, in charge of the inquiry, subsequently accepted the main conclusion of the Farnborough Report, that the cause of the accident to the Elba Comet was the structural failure of the pressure cabin brought about by fatigue. Owing to the absence of wreckage at Naples, Lord Cohen could but agree with the opinion suggested in the Farnborough Report.

Metal Fatigue

The assessors gave general information on metal fatigue, stating that the fatigue of metals has been studied for upwards of 100 years, and

Fig. 5 – A Considerable Portion of the Wrecked Structure of G-ALYP ("Yoke Peter") Had Been Recovered From Sea Bottom Near Elba and Fitted Together on a Wooden Skeleton

there is a world-wide literature about it. The name correctly suggests that metals (and indeed other materials) suffer from a type of weakness not unknown to human beings. They will break after loads which are repeatedly applied and removed, even though they can support a much larger steady load without distress.

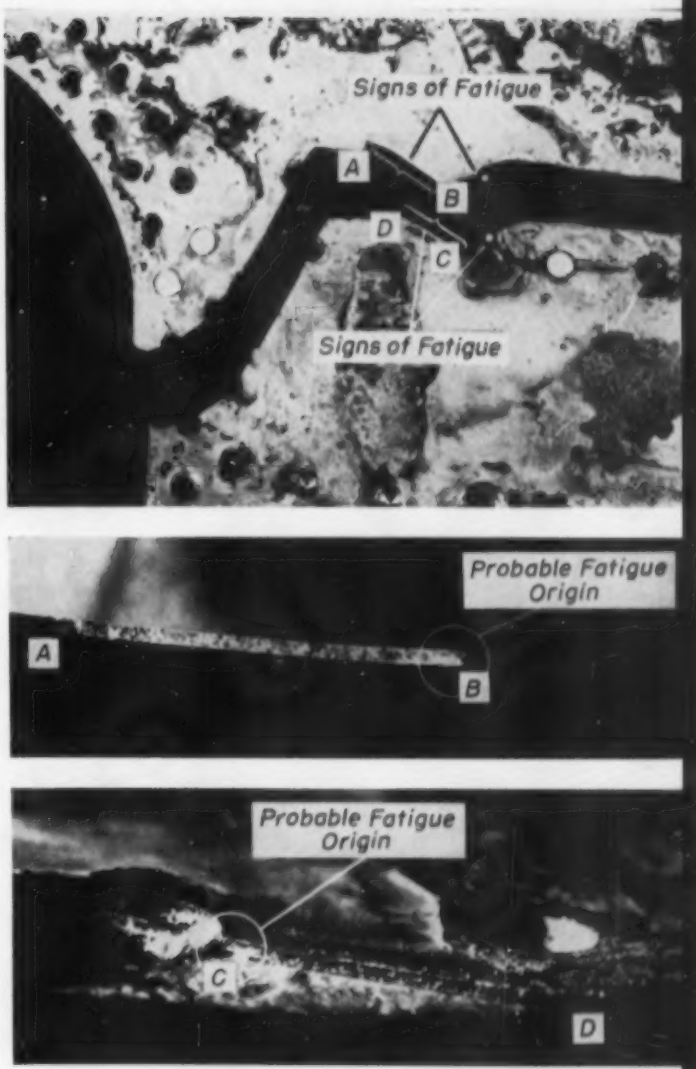
There is one generalization which applies to all failures due to fatigue. The higher the intensity of the stress (unit load) caused by the external load, relative to that which would just cause failure when applied once, the lower is the number of applications of that load under which failure by fatigue will occur. The higher or more intense the repetitive load, the shorter the life will be.

A second generalization applies to certain materials (in particular steel – though not, in general, to alloys of aluminum): There is a sizable fraction of the ultimate strength below which fatigue is borne indefinitely. This is usually termed the endurance limit.

Enough is now known about the fundamental physics of metallic fracture for engineers to be aware that there is still much to be learned about fatigue. Research is continuous. But this relates more to discovering how to improve the resistance of materials to fatigue than to removing any doubts about the principles which should govern the design of engineering structures which must have long life under fluctuating loads. This is true both of mechanisms (such as rotating machinery where the number of cycles of loading in an economic life runs into millions or billions, and the computed loads of service must then be below the endurance limit), and of relatively static structures, such as bridges, or the wings or pressure cabins of aircraft, where the alterations which must be carried safely are numbered in thousands, and hence the unit stress computed for the principal members can be somewhat higher.

Designs to take advantage of a higher level of stress than the one just mentioned are comparatively rare. Virtually no engineering components are designed to have a *short* life under alternating loads. Nor would it be easy so to design them with any confidence since the "scatter" of experimental points defining the upper leg of the so-called S-N curve is very high. There-

Fig. 6 – Small Areas in Fracture of Skin Plates From "Yoke Peter" Recovered From Sea Near Elba. Top view of broken skin is about two-thirds size; middle and bottom views of edge at A-B and C-D respectively of broken 20-g. (0.036-in.) sheet are magnified about three times. These tiny fatigue cracks were found when stripping an area around an aerial window for a radio direction finder



fore the symptoms of failure after relatively few cycles are quite unfamiliar; they are also less specific. The process has not gone on very long, and most of the obscure symptoms of a disease which spreads gradually are absent. This is not to say that fatigue failures in machinery are rare – quite the opposite. But these result from unanticipated variants either in the fabrication shops or in service which introduces "stress raisers" into the part which fails – usually notches, scratches, or corrosion roughening. The uninitiated and the mechanic have a pat (but completely erroneous) name for such failures: "recrystallization".

In the evidence given by Alfred J. Murphy, professor of industrial metallurgy at the University of Birmingham, are two remarks which summarize the situation as seen by an experienced metallurgist. He said:

"I am strongly impressed by the high general level of stress around the corners of the cabin windows, and I do not feel it necessary or even relevant to try to pursue the last final speck, as it were, which set off the fatigue failure. I think in various places there was a readiness for fatigue failure, and it required only a mild stress raiser (such as a rivet or bolt hole) to initiate failure . . . The prime consideration is, I think, to get the general stress level down so that you are not in jeopardy in this way. If you can get the general stress level down, you can tolerate the variations which are very liable to happen in practical manufacture. If you have a high stress level, you are setting yourself the task of guarding against most minute variations from the ideal."

The Comet investigation and other research have resulted in a wealth of new knowledge and will benefit aviation throughout the world where it is heeded. This knowledge will be built into new British aircraft coming along. The makers of the Comets, de Havillands, have stated that, among other future measures, they propose to use thicker-gage materials in the pressure cabin area and to strengthen and redesign windows and cut-outs, and thus lower the general stress to a level at which local stress concentrations – either at rivets and bolt holes, or such as may occur by reason of cracks caused accidentally during manufacture or subsequently – will not constitute a danger. In addition, de Havillands are already engaged on an extensive program of detailed testing to establish a design technique which will minimize the effect of such local stress raisers as are necessarily inherent in the design.

The Minister of Transport recently announced that the decision has been made to go ahead with the employment of the redesigned Comets II and III on a large scale.

Cast Bolts for Pipe Joints

*By C. K. DONOHO**

Cast bolts are mass-produced in metal molds with short-cycle annealing; nuts are gray iron, shell molded. They combine good mechanical properties and corrosion resistance for joints in pipe lines.

A NOVEL metallurgical process is used by American Cast Iron Pipe Co. to produce cast iron bolts for mechanical joints in cast iron pipe. White iron bolts are cast continuously in metal molds mounted on turntables and malleablized by annealing. The unique feature of the process† is that, because of the quick freezing in the metal molds, the silicon content of the iron can be run as high as 3%. Such material can be annealed in about one-tenth the time required for conventional sand cast malleable analyses.

The annealed bolts have good machinability for threading, about 60,000-psi. tensile strength with adequate toughness, and corrosion resistance at least comparable to that of the cast iron pipe with which they are used.

A cross section of a typical mechanical joint for cast iron pipe will illustrate the use of the bolts to maintain permanent compression of the rubber gasket. (See drawing on opposite page.)

Bolt Production – The molten metal is obtained from a 30-in. cupola melting about 2 tons per hr. The metal charges consist essentially of steel scrap, return bolt scrap, and high-silicon pig iron. Copper is added up to about 1% for corrosion resistance – as will be discussed toward the end of the article. The desired compositional limits are: total carbon 2.40 to 2.80%, silicon 2.60 to 3.20%, sulphur 0.15% max., phosphorus 0.15% max., manganese 0.60% max., copper 0.60 to 1.00%. When this metal is poured into the cast iron molds a completely white fracture casting is obtained.

Molds are closely mounted side by side on two turntables, 60 molds to each bolt "wheel". These molds are machined from soft cast iron blocks, and the metal is poured into them from suspended hand ladles. As the motor-driven turntables slowly revolve, the two halves of the bolt mold close and are clamped together at the pouring station, then are automatically separated, after the bolt is solidified, and the hot bolt removed from the mold.

Casting rate can be maintained at about 30 bolts per min. per turntable, or up to one bolt per second for the complete operation. The mold coating is acetylene soot automatically applied to the mold cavities just before the pouring station. Mold temperatures are controlled by adjustable water sprays.

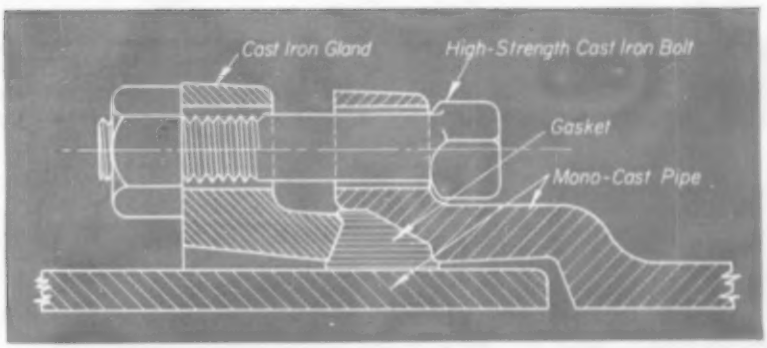
Malleablizing heat treatment is in a continuous pusher-type gas-fired furnace. Bolts are loaded on alloy trays, heated to 1700° F., held 45 min., then cooled in about 1½ hr. to 1250° F., and finally air cooled. The complete cycle can be carried out in 4 to 5 hr.

Annealed bolt blanks are tumbled to remove

*Chief Metallurgist, American Cast Iron Pipe Co., Birmingham, Ala.

†U.S. Patent No. 2,220,792.

Cross Section of a Mechanical Joint for Cast Iron Pipe



scale and then threaded in automatics. The decoration at the head of this article shows a variety of cast bolts which we produce. Actual sizes range from ⅝ to 1½ in. in diameter and up to 8 in. long.

Nut Production – Extensive testing has proved that the high tensile strength required for the bolt metal is not necessary in the nuts. Accordingly nuts are cast of a normal foundry grade of gray iron, and in sand by the shell molding process. The 20 × 30-in. pattern plate used for ¾-in. nuts carries 160 individual patterns gated into two common runner systems. About one complete shell is made per minute.

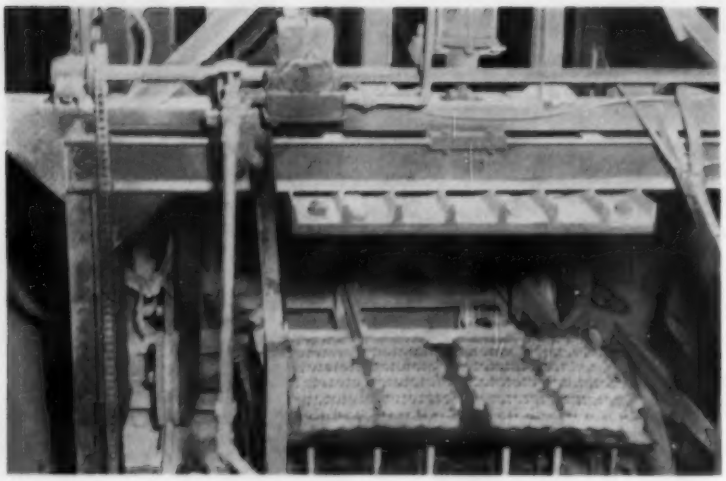
In operation, a sand mixed with 4% of resin is dropped on the hot pattern. The pattern plate immediately passes under a radiant heater to cure the top surface of the resin sand. After curing, the pattern is inverted and the shell mold ejected downward as shown in the halftone on the following page. Shells are backed by coarse gravel sand for casting.

Nuts are given a low-temperature anneal for stress relief and to insure uniform machinability in the tapping operation. They are cleaned by tumbler and then reamed and tapped in automatic machines.

Quality Control – Mass production operations of this sort are particularly amenable to statistical quality control. In our bolt manufacturing, such control starts with inspection and testing of the incoming raw materials. Hourly chemical analyses of the molten metal plus periodic spectrographic checks on residual or tramp elements provide the basis for composition control. Regular fractures of as-cast bolts plus standard wedge chill tests measure the "mottling" tendency of the melted metal. The efficiency of the annealing treatment is controlled by making regular Brinell hardness and bend tests on bolt blanks emerging from the continuous annealing furnaces. Rockwell hardness testing checks the efficacy of the heat treatment of nuts. Final proof testing of finished bolt-nut assemblies is done in a pneumatic tension machine applying an appropriate axial pull – equivalent to 50,000-psi. unit stress for the ¾-in. size. This final proof testing is not a 100% inspection but is carried out on lots selected by a statistical sampling scheme designed to assure us that less than 0.5% of outgoing bolts will have a yield strength lower than 50,000 psi.

Engineering Properties – A typical microstructure of annealed bolt metal is essentially temper carbon nodules in a matrix of silicoferrite. The effect of nearly 3% silicon and 1% copper in solid

Three-Man Crew for Casting Bolts From Hand Ladles on Revolving Turntables at a Rate of 60 Per Min.



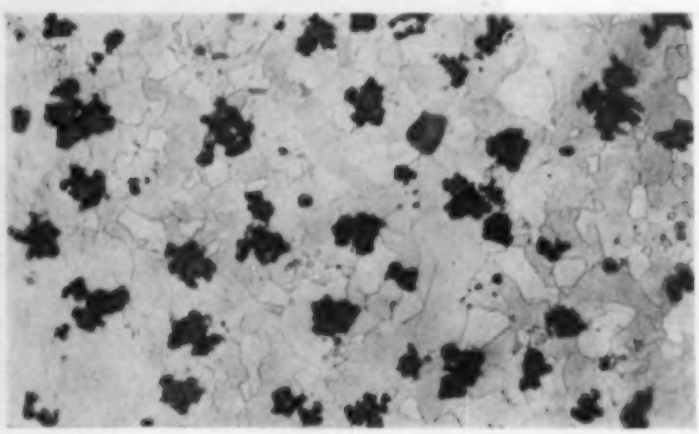
Shell Mold for 160 Nuts After Stripping From Horizontal Pattern Above. Cycle: one mold per min.

solution in the ferrite is to increase the hardness and strength considerably above that of ordinary malleable iron although ductility is lowered.

A typical stress-strain diagram of a 5.05-in. tensile bar cast of standard bolt metal and malleablized shows a straight-line relationship up to about 45,000 psi. and a modulus of elasticity of 21,000,000 psi. Yield strength (at 0.2% offset) is 60,000 psi.; ultimate is 70,000 psi., and elongation at fracture is 5.3%. Having around 5% elongation, the bolt has enough ductility to resist bending stresses which may be encountered in normal service – due to settlement of pipe in a trench, say – yet the ductility is not enough for the bolt to stretch if an over-eager workman tightens the nut unduly.

When these bolts were first produced in 1937, a copper-free metal was used (except for tramp copper). It was found that, in some installations such as condenser piping submerged in sea water, the bolts and nuts were failing while the pipe was still serviceable. Since iron is made more cathodic by alloying with more noble elements which form simple solid solutions, copper was introduced and found to make the bolts cathodic (in most electrolytes) to the copper-free or low-copper pipe metal with which they are in electrical contact.

This change decreased complaints about bolt corrosion. An unplanned confirmation of the benefit of copper occurred during World War II when copper was not available for alloying. For several years afterwards complaints of bolt corrosion could almost always be traced to the copper-free bolts that had been produced during the critical war years.



Annealed Bolt Consists of Temper Carbon Nodules in Ferrite Containing Silicon and Copper in Solid Solution

Arc-Cast Molybdenum– Ingot to Bar, Sheet or Wire

*By N. L. DEUBLE**

The second in a series about arc-cast molybdenum and molybdenum-base alloys. Hot ingots are covered with slippery molten oxide and extrusion is better than forging for initial reductions. Further rolling to bars and sheet, hot swaging to rod, and hot drawing in diamond dies give little difficulty.

ARC-CAST molybdenum has a coarse structure as cast, which requires considerable mechanical working to make it fine-grained. In ingots made by powder metallurgy the grain size, as sintered, is fine.

For a number of commercial metals and alloys, the normal forging temperature is about 80% of the melting point, which would be around 3800° F. for molybdenum. Since no commercial equipment is available for forging and handling such hot material, methods of working with present facilities have had to be developed. Forging tests over the range 2000 to 2800° F. showed that properly deoxidized molybdenum worked best at 2200 to 2400° F.

It also appears that the workability of ingots is determined largely by the molybdenum melting process. Forgeability is related to deoxidation. If deoxidation is not complete, plates of molybdenum oxide can be observed in the fracture at high magnifications; such material will crack in forging even under the most favorable conditions. On the other hand, completely deoxidized molybdenum is readily forgeable. In the Climax process, described in *Metal Progress* last month, the rate of melting has a considerable effect on surface quality, since splatter on the mold walls is not remelted and will cause surface defects. All ingots, therefore, are turned before further processing. (The chips are salvaged by remelting.)

Rolling and Forging – Rolling of arc-cast molybdenum ingots to bars was attempted first. In the early stages, a 2-in. round ingot was successfully rolled on a toolsteel mill. Subsequent attempts to roll similar and larger ingots with

*Manager, Metallic Molybdenum Sales, Climax Molybdenum Co., New York City.

*Fig. 5 – Forging Molybdenum on 600-Ton Hydraulic Press at Climax Laboratory**

hand-round passes, using rather light reductions at 2200 and 2500° F., failed – the ingots cracked, usually after the second or third pass.

Forging attempts ran into difficulties because of the rapid oxidation of molybdenum above 1800° F. Under some conditions, the oxide does not sublime immediately but forms a liquid on the surface; the ingot is then very slippery and difficult to handle. Because of the liquid oxide, it was almost impossible to hammer ingots between flat dies; such flat dies also developed a bad stress pattern, which usually resulted in 45° cracks from the corners. Round swaging dies were not suitable because of the slow rate of working. The combination of a flat upper die with a lower die having a 90° Vee proved satisfactory because the metal was prevented from slipping and the stress pattern was favorable. See Fig. 5.*

In forging an octagon with this set-up, the force of the blows had to be limited to maintain satisfactory shape; this also minimized cracking. A 4-in. diameter ingot, 30 in. long, could be forged to a 2-in. octagon even though it was necessary to reheat as many as 18 times. (Molybdenum has high thermal conductivity and low specific heat.) A number of 6-in. diameter ingots 30 in. long were forged to 4-in. octagons, but yields were low because of end cracking and oxidation losses. Forging a 9-in. ingot on a 1500-ton hydraulic press also proved discouraging because of cracking.

Extrusion – Under these circumstances we turned to extrusion, which would keep the metal under compression from all directions. This ought to be the ideal way of reducing ingots to billets for further conversion. Early trials failed because of inadequate press capacity and lubrication, even though extrusion ratios as low as 2 to 1 were used.

In 1950 we heard of a new process using high-speed presses and glass as a lubricant (the Ugine-Séjournet process), developed in France by Comptoir Industriel d'Etirage et Profilage de Métaux. Drilled ingots sent to France were successfully extruded to tubes in March 1951 (Fig. 6). Later, ingots of molybdenum-base alloys were sent to France and extruded into round and flat bars for rerolling.

Meanwhile, several companies in the United States were licensed under the Ugine-Séjournet process, so arrangements were made with one of them, the Babcock & Wilcox Co., to extrude arc-cast molybdenum ingots into billets for rerolling (Fig. 7). An extrusion ratio of 4 to 1 is usual for unalloyed molybdenum ingots, and 3 to 1 for alloyed. Because of such small reduction the surface is not particularly good. There is considerable opening-up of the forward end of the extrusions (Fig. 8), but we are hopeful that this loss can be reduced.

Molybdenum requires considerably more lubrication than Type 304 stainless steel. In a salt bath, 2300° F. is satisfactory for either unalloyed or alloyed ingots. When molybdenum-base alloys were heated in a small gas-fired furnace, the lowest extrusion pressures were obtained at 2600° F. The lower temperature with salt-bath heating probably results from better adhesion of the glass to the salt-coated surface, and hence better lubrication in the die. Raising the temperature above 2600° F. did not lower the extrusion pressure for gas-heated alloys.

Some special development work, using induction heating, is in progress at Babcock & Wilcox Co., that indicates that less ram pressure is required with this type of heating than with either salt bath or gas furnace. With this new method

*Figure numbers are continued from the first installment in this series, published in April *Metal Progress*, p. 87.

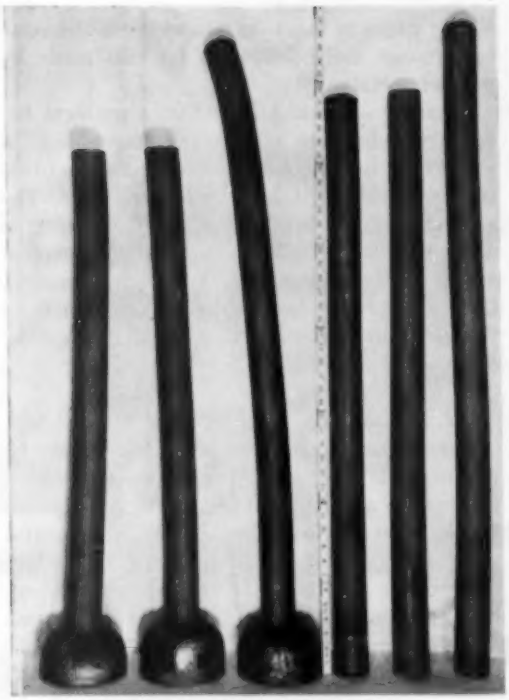


Fig. 6 – Tubes Extruded by Ugine-Séjournet Process From Drilled Molybdenum Ingots

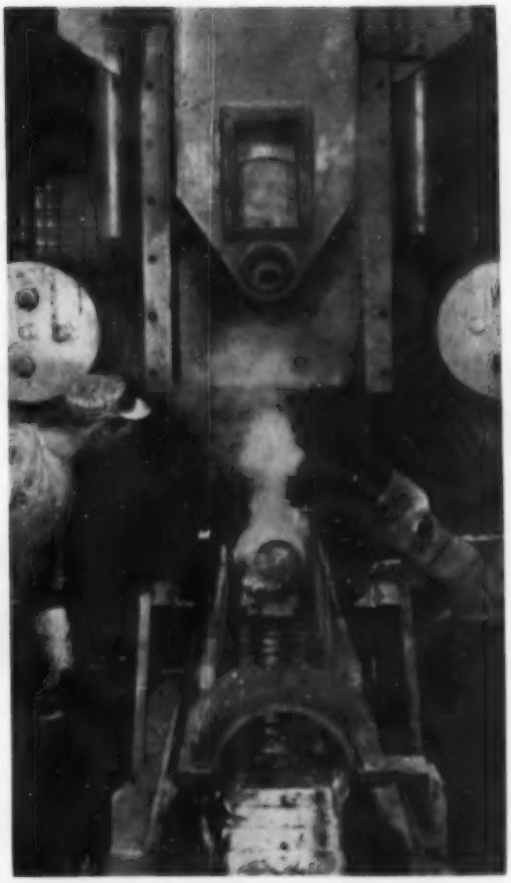


Fig. 7 – Molybdenum Billet Coming From Extrusion Press (Babcock & Wilcox Co.)

there is less loss due to bursting of the front end of the extrusion, thus increasing the yield. The largest unalloyed molybdenum ingot extruded to date was 8¾ in. in diameter and weighed more than 400 lb.; it was extruded to a 6-in. round. With induction heating, it is anticipated that larger extrusion ratios will be possible.

At present time, extrusion is used exclusively to break down unalloyed and alloyed arc-cast ingots into billets for rerolling. Normally, turned ingots, 6¾ in. in diameter, 20 in. long, weighing about 260 lb., are extruded into bars about 4 in. in diameter. Smaller sizes can be extruded from unalloyed molybdenum, but this would be pointless since a 4-in. round can be rolled satisfactorily and handled more economically.

Extrusion is safer than forging because no hazard is presented by slippery ingots. In addition, the extrusion process gives a better yield of sound stock at lower cost than is possible with forging, for the following reasons:

1. Only a single heating is needed for extrusion; with salt-bath heating, there is no oxidation of the ingot. On the other hand, with gas heating and forging, weight losses from repeated heating can be as much as 10 or 12%.

2. During extrusion, the molybdenum is under uniform compression; in forging, this is not so. Uniform compression in extrusion minimizes cracking, so larger yields of sound material are obtained.

Processing of Extrusions

Glass-covered extrusions (Fig. 9) must be conditioned before rolling. This consists of removing the glass, cropping the ends to sound material, heating to recrystallize the structure, straightening, turning to remove surface defects, and nosing. The turned extrusions, generally about 3¾ in. round, are then rolled to bars 3 in. round or less (depending on the application) on a toolsteel hand-round or guide mill. Temperatures are 2400 to 2100° F. It is usually necessary to reheat during rolling because the metal cools so rapidly

that the bars will not enter the roll passes or guides. Generally, no particular trouble is encountered in rolling bars down to ¾ in. round.

Sizes under ¾ in. are processed in the same way as powder-metallurgy molybdenum. Details vary from plant to plant but the ¾-in. round bars are generally swaged in an automatic machine, where the bars are heated just before entering the dies and fed automatically so their temperature is suitable for the bar size and speed involved. Swaging is replaced by hot drawing (usually through diamond dies with a special lubricant) at about 0.1 in. diameter. Wires as fine as 0.0012 in. have been drawn from arc-cast molybdenum-base alloys.

For sheets, the 3¾-in. rounds are rolled to sheet bar, approximately 1 × 3¾ in. These are cropped, recrystallized and cut to length for rerolling. Heavy initial reductions of the sheet bar are necessary to avoid laminations in the final sheet. The breakdown temperature is nominally 2500 to 2200° F. After a reduction of area of at least 50%, the temperature is gradually dropped so 0.060-in. sheet, for example, is finished at 1500° F. For lighter gages of sheet the processing is the same for arc-cast molybdenum as for that made by powder metallurgy.

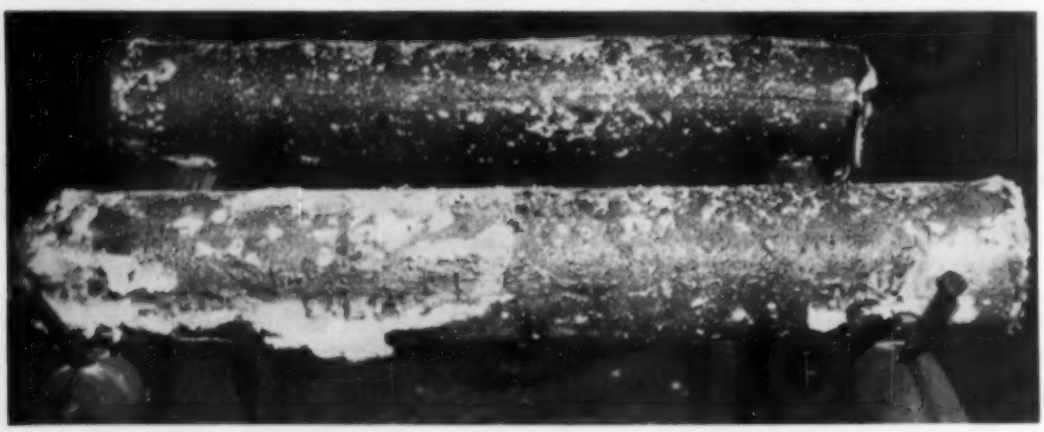
Cleaning – Pickling is seldom a problem because molybdenum is normally free-scaling. A vapor blast is the easiest way to remove an oxide coating, but a grit blast will also serve. The only chemical means for removing a coating is a molten caustic bath, although this involves safety hazards inherent in any such operation. Good results have been obtained with a bath of 90% potassium hydroxide and 10% sodium nitrite, operated at 600° F.

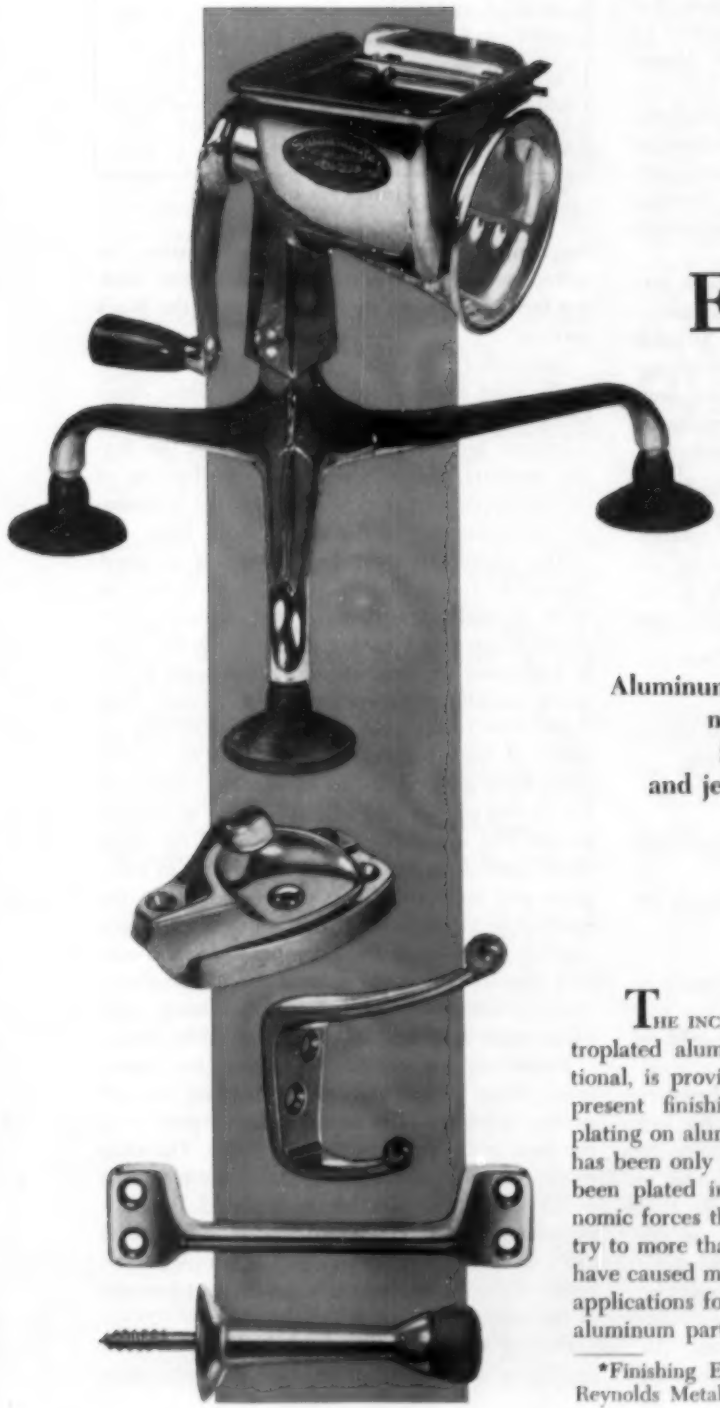
The Future

Larger bars and sheets will undoubtedly be produced in the near future when extruded billets with a turned diameter of 5¾ in. by about 3 ft. long become available. When more powerful extrusion presses, better lubrication, or higher-temperature heating furnaces are developed, larger sizes will be possible. Still heavier sections of arc-cast molybdenum would require new facilities for melting as well as extruding.

Fig. 8 – Cropped Ends of Molybdenum Alloy Extrusions. Half size

Fig. 9 – Surface of Extruded Billets Before Removal of Glass Lubricant





Electroplating on Aluminum

*By R. F. HAFER**

Aluminum plated with most of the common metals is being put to increasing use in hardware, electrical equipment and jewelry. Careful surface preparation is needed to obtain sound and adherent electrodeposits.

THE INCREASING number of applications for electroplated aluminum parts, both decorative and functional, is proving the practicality and economy of the present finishing processes. Although processes for plating on aluminum were available as early as 1928, it has been only in the past few years that aluminum has been plated in production quantities. The same economic forces that have influenced the aluminum industry to more than double its refining capacity since 1946 have caused manufacturers and fabricators to find more applications for aluminum and consequently for plated aluminum parts. Successful use of electroplating proc-

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esses for aluminum is dependent on the solving of several inherent problems, most important of which is the removal of the oxide or hydroxide film that prevents satisfactory adherence of metal deposits. Alloying greatly affects the chemical and electrochemical activity of aluminum. For this reason most electroplating practices must be modified to some extent for each alloy. Aluminum and its oxide are amphoteric and are subject to attack in many standard plating solutions. On account of its position in the electrochemical series, aluminum replaces the more positive metals from their solutions, generally forming spongy, loosely adherent deposits of these metals on its surface.

The type of product must also be taken into consideration. Castings are not usually as metallurgically sound as wrought products. Suitable steps must be taken to avoid the possible entrapment of plating solutions in porous areas since entrapment may lead to serious local corrosion and subsequent blistering of the electrodeposit.

It is important that electrodeposits on aluminum, particularly under severe corrosive conditions, be sufficiently thick and of good quality. Metals plated on aluminum and its alloys are generally cathodic to it, and thus voids in the electrodeposit make the base metal highly susceptible to localized galvanic corrosion.

Plating Processes

Four basic ideas have been evolved to obtain adherence of electrodeposits on aluminum:

1. By mechanical keying to etched or mechanically roughened surfaces.
2. By anodizing to produce porous or modified aluminum oxide films.
3. Forming suitable initial films of metals by immersion plating.
4. Direct electrodeposition.

It should be pointed out that because many of the processes described in this article are still subject to patent claims, the patentee should be consulted before these processes are put to use.

In 1928, H. K. Work of the Mellon Institute developed what is generally regarded as the first commercial process for electrodeposition on aluminum. The principle of the process was to etch so as to produce undercutting pits that would serve as mechanical keys for the subsequent electrodeposit. Control of the etching solutions was difficult and bright surfaces could be obtained only by considerable mechanical finishing of relatively thick electrodeposits. Attempts to produce suitable keying surfaces by mechanical methods, such as sand-blasting, resulted in fair adherence; the limitations of blasting techniques were similar to those of the Work process.

Operating Conditions for Phosphoric Acid Anodizing

Alloy	Temperature	Current Density†	Voltage	Time
Solution of 85% H_3PO_4 in water to sp. gr. of 1.300				
1100	87° F.	12	22	5 min.
3003	85	12	22	5
5052	85	12	25	10
6061	85	12	22	7
Solution of 85% H_3PO_4 in water to sp. gr. of 1.1134				
2024	75	10 to 15	5 to 26	10
No. 13*	95	17	17	15

*Casting alloy. †Amp. per sq. ft.

Satisfactory electrodeposits can be made directly over porous aluminum oxide films, these being produced by anodizing in phosphoric acid solutions. Since the anodic film acts as the keying medium, the adherence and uniformity of the electrodeposit is dependent on the uniformity and adherence of the anodic oxide film.

The aluminum must be thoroughly cleaned, then etched very slightly in caustic soda or solutions of sodium carbonate and sodium phosphate. Following cleaning and etching, the work is immersed in concentrated nitric acid to remove metallurgical contaminants, rinsed, then transferred to the phosphoric acid anodizing solution. A concentration of 53 to 55.5 oz. of 85% phosphoric acid per gallon of solution works well for all but copper and silicon-bearing aluminum alloys. The anodizing solution should be made with distilled water or with water low in halogens and sulphates. The concentration of the electrolyte is not critical for wrought products, but the variables of time, temperature, and current density are quite critical for all products. The operating conditions for anodizing with phosphoric acid are listed in the table above.

Following the anodizing treatment the aluminum can be plated from many standard low-pH plating solutions. The initial electrodeposit is at the base of the pores in the oxide film. The electrodeposition gradually extends through the pores until the surface becomes plated. Poor adherence can generally be attributed to films that are too thin or too porous, and incomplete coverage of the electrodeposit to insufficient porosity of the oxide film.

Plating over films made by phosphric acid anodizing is sensitive to surface discontinuities

and irregularities. Also, suitable oxide films can be formed on only a limited number of alloys. For these reasons the process has only limited commercial application.

There are several other processes involving anodizing techniques, but they have not found wide commercial applications in the United States. The best known of these are the "Elytal Process" and the "Krome Alum Process". In these processes electrodeposition is made over anodic films that have been cathodically reduced in the plating bath, or on anodic films modified in sodium cyanide solutions to obtain the desirable porosity.

Zinc Immersion Process

The commercial practice being used at present to preplate aluminum and its alloys for subsequent electroplating is the sodium zincate or the zinc immersion process. This was first described in 1927; since that time modifications have been made in both the zincating solution and in the methods of surface preparation prior to the immersion deposit. The current recommended practice for the preparation and electroplating of aluminum and its alloys is described in A.S.T.M. Designation B 253-53. The basic procedures for this process are: (*a*) cleaning, (*b*) surface conditioning, (*c*) zincating and (*d*) electroplating.

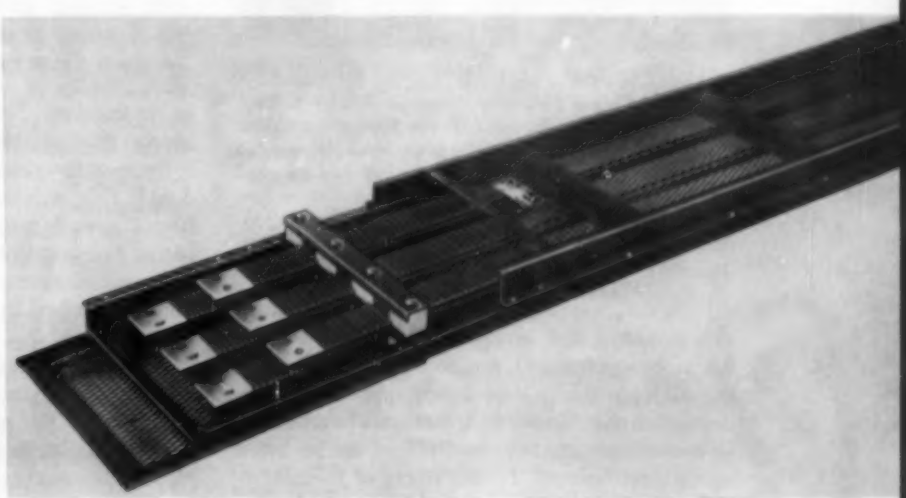
Cleaning – It is essential that the surface be free of oil, grease, and other soils prior to surface conditioning. The use of mild etching or inhibited alkaline cleaners is recommended. If the surface is heavily contaminated with grease and oil, solvent or vapor degreasing may be required.

Surface Conditioning – The surface of the aluminum must be conditioned after cleaning so that an adherent and continuous metallic zinc film is deposited during the preplate immersion. For most wrought alloys a conditioning treatment consisting of immersion in a 15% solution of sulphuric acid (specific gravity 184) maintained at 175 to 185° F. for 2 to 5 min., followed by rinsing, and a 15-sec. dip in a 50% solution of nitric acid (specific gravity 1.42) is recommended. For wrought alloys of the magnesium silicide type the addition of ½% by volume hydrofluoric acid to the nitric acid solution is beneficial. Although this treatment is satisfactory for many casting alloys, alloys containing appreciable amounts of silicon should be conditioned for 3 to 5 sec. in a solution of three parts nitric acid (specific gravity 1.42) and 1 part hydrofluoric acid (48% HFl).

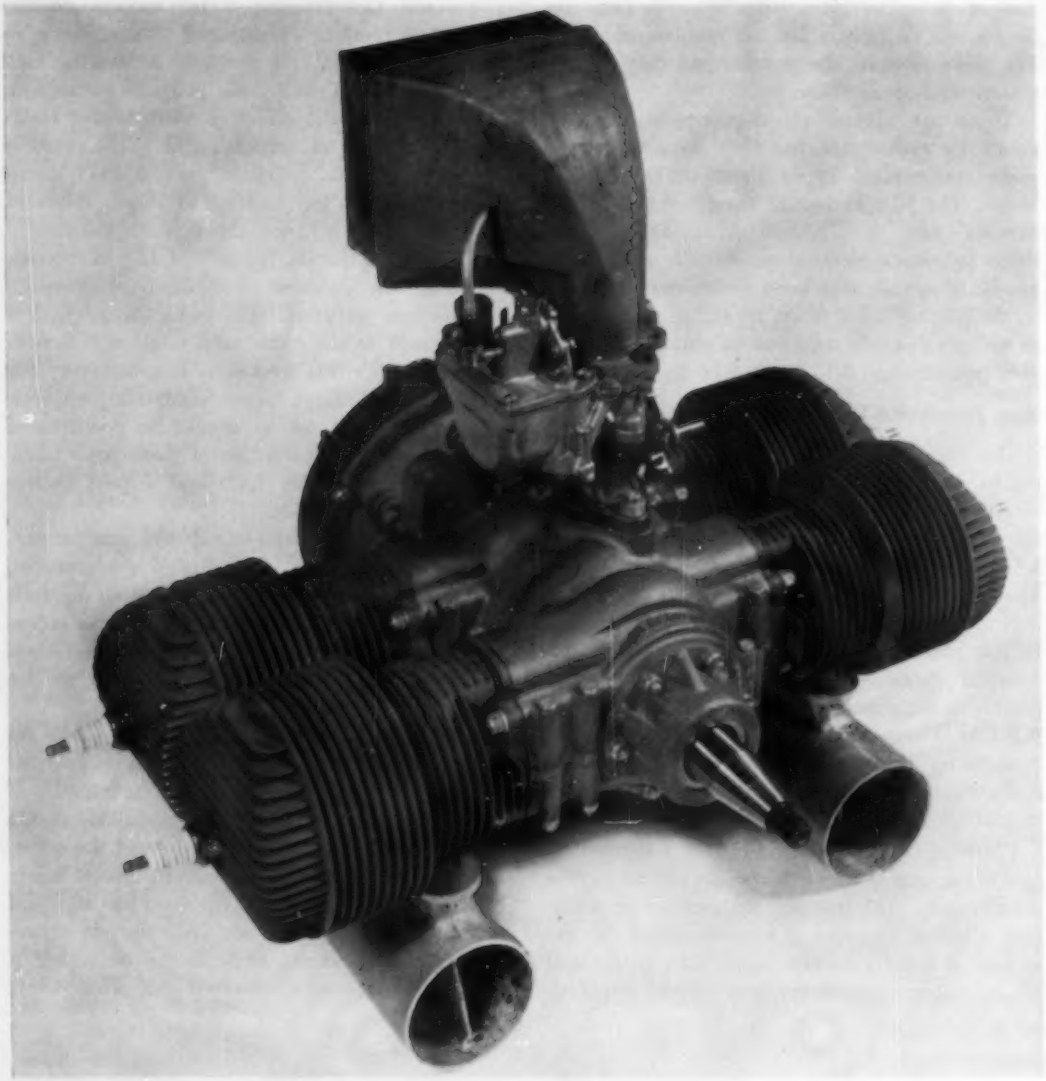
Zincating – The principle of the zinc immersion process is one of chemical replacement, aluminum ions replacing zinc ions from aqueous solutions containing zinc salts. With proper cleaning and surface conditioning, a thin, adherent film of metallic zinc will be deposited on the aluminum surface.

The standard zincating solution is made up of 525 g. per l. of commercial sodium hydroxide and 100 g. per l. of technical zinc oxide.

Although this solution is highly alkaline, the aluminum is etched only slightly and the adhesion of the zinc film is dependent almost solely on the metallurgical bond between the zinc and aluminum. The quality and adhesion of subsequent electrodeposits depend on obtaining a thin, adherent and continuous zinc film. Alloy,



Section of Busbar Distributor System. Light-colored portions (ends of bars and blocks holding the bars) are silver plated. (Courtesy Bulldog Electric Products Co.)



A Four-Cylinder, Two-Cycle Engine of Aluminum Made by Nelson Specialty Corp. for Glider Service Uses Van der Horst Corp.'s "Porus-Krome" on Cylinder Bores. Designed originally to incorporate nitrided iron sleeves, the porous chromium plate was adopted to improve heat transfer, reduce wear and to reduce the weight-to-horsepower ratio to a minimum. (Courtesy of the Van der Horst Corp. of America)

surface conditioning, and variables in the immersion process (such as time, temperature and solution concentration) are factors. Copper-bearing alloys reach a state of equilibrium of zinc deposition more rapidly than other aluminum alloys and are generally considered to be more easily electroplated. Temperatures of the zincating bath much above 80° F. produce loosely adherent, granular zinc deposits.

Because the zincating solution is quite viscous, double rinsing is needed to remove it completely from the work prior to its entry into the plating baths. For applications where solution drag-out is serious, zincating solutions of lower concentrations (described in A.S.T.M. Designation B 253-53) are available.

Plating – The zincate-treated aluminum can be plated with methods generally suitable to plating zinc. For many applications a Rochelle-type copper-strike solution of low PH is employed; however, chromium, nickel, silver, cad-

mium and brass can be plated directly on the zinc deposit from suitable plating solutions. There are several excellent proprietary plating processes that employ modified zinc practices. Two of the most widely used are the "Alumon" process offered by Enthone, Inc., and the "Alumetex" process, offered by MacDermid, Inc. Considerable work has been done in this country and in England to evolve a practical method for electrolytic deposition of zinc.

Applications

At least two companies have in operation fairly extensive automatic systems for electroplating aluminum, and the number of job shops commercially plating aluminum has almost doubled since 1946. The greatest potential use for plated aluminum parts seems to be in the automobile and appliance industries. There are many good reasons for assuming that in such applications plated aluminum may replace zinc die castings and perhaps plated stainless steel. Although plated aluminum die castings have not yet been accepted by the automotive industry, the replacement of zinc die castings with aluminum is under very close scrutiny by most automobile manufacturers.

Aluminum holds a decided edge in basic metal costs, particularly for large castings, and improvements in die steels and casting technique are slowly bringing the operational costs for die casting zinc and aluminum more closely together. It has been pointed out that zinc and aluminum die castings require the same thickness of electrodeposits for best corrosion protection. Since it is anticipated that specifications for plated automotive parts will tighten, this action would also work in favor of aluminum. In 1948 the Chrysler Corp. used aluminum bumper guards on certain models. The guards, made by permanent mold casting, were plated with a copper-nickel-chromium system. This practice is carried on today by several automotive manufacturers with excellent results.

Decorative bright chromium, brass, and the more noble metals, silver, gold and platinum are currently being plated on aluminum for a variety of every-day items.

Die-cast freezer and refrigerator handles, plated with copper-nickel-chromium, represent one of the current large-volume items. Such household and restaurant items as saladmakers, juicers, and cream dispensers are also being bright chromium plated. Several companies are marketing chromium plated coffee makers. For this application chromium is generally plated directly over the preplate zinc and buffed to the desired luster.

Brass-plated aluminum hardware, such as window latches and pulls, coat hangers and door stops, is in wide use. Much of this work is done by barrel plating techniques or in automatic plating systems. Cadmium-plated cast aluminum hardware also gives excellent results. Brass, silver, and gold-plated aluminum jewelry is quite common. A midwestern company manufactures a line of gold-plated religious items. However, the applications where functional plating on aluminum is used exceed the application for decorative plating.

Perhaps the greatest possibilities for electroplated aluminum are in the electrical industry, for busbar, bus-duct, switch-gear, and other current carrying equipment. For these applications silver plate is used to eliminate the formation of aluminum oxide (which has high electrical resistance), to increase the efficiency of mechanical joints and to minimize the likelihood of corrosion at the joints of copper and aluminum conductors. Aluminum plated with copper, nickel, tin and cadmium facilitates joining by soldering and brazing.

Electrodeposits of many types are used to increase the resistance of aluminum to wear and abrasion and to improve its frictional characteristics. Hard chromium is used to increase the wear resistance on aircraft landing gear, X-ray equipment and many types of hydraulic and small engine cylinders and pistons. The Van der Horst Corp. of America has developed a "Porus Krome" plating process which has been very effective in increasing the life and efficiency of aircraft and small engine cylinders. A relatively heavy hard chromium deposit is etched preferentially to form many small pores which act as lubricant reservoirs. Zinc and tin are used effectively to improve the frictional characteristics of aluminum.

Plating of aluminum has come of age. Plated parts are now being effectively and economically used in many products. This successful experience over the past few years is rapidly dispelling the reluctance that fabricators once held to employ this finishing process.

Photographs on p. 93 are of saladmaker, die cast of No. 380 aluminum casting alloy, plated with copper-nickel-chromium (Courtesy Salad Master Sales Co.), and hardware made by permanent-mold casting of No. 356 aluminum casting alloy, decoratively plated with brass (Courtesy Sargeant & Co.).

Fall-Out From an H-Bomb*

A NUCLEAR detonation produces four major characteristics — blast, heat, immediate nuclear radiation, and residual radioactivity. The first three are essentially instantaneous. Information on blast and heat effects has been extensively publicized.† The *immediate* nuclear radiation, that is, the neutrons and gamma rays released instantaneously with the explosion, does not present a serious hazard beyond the area where heat and blast are of great concern.

"Fall-out" applies to a phenomenon that follows the explosion of a nuclear weapon. If the fireball touches the earth, it draws up large amounts of materials into the bomb cloud, which fall back as radioactive particles over a large area, mostly down-wind and relatively close to the explosion — although the lighter particles are carried great distances. The main radioactivity of fall-out decreases very rapidly with time — for the most part, within the first hours after the explosion. An explosion in the air where the fireball does not touch the earth's surface does not produce any fall-out hazard.

Residual radioactivity, or fall-out, is a matter of major concern when large thermonuclear devices are exploded. Only relatively small nuclear test explosions are conducted at the Nevada test site and heavy fall-out has extended only a few miles. However, the very large thermonuclear device tested at Bikini on March 1, 1954, was detonated on a coral island and the fall-out contaminated an elongated, cigar-shaped area extending 220 miles, plus an area up-wind and cross-wind extending possibly 20 miles. Data were collected from 25 points located up to 330 miles down-wind.

Data from this and other tests permit estimates of casualties which would have been suffered within this area if it had been populated. These estimates assume the worst possible conditions: *(a)* that the people would ignore even the most elementary precautions; *(b)* that they would remain outdoors completely exposed for 36 hr.; and *(c)* that in consequence they would receive the maximum exposure.

It is estimated that, following the March 1, 1954, test explosion, there was sufficient radioactivity in a down-wind belt about 140 miles in length and of varying width up to 20 miles to have seriously threatened the lives of nearly all persons in the area who took *no* protective measures. Some distance further (about 160 miles down-wind) the radioactivity would have seriously threatened the lives of about half of the persons who took no protective measures. Near the outer edge of the ellipse (approximately 190 miles down-wind) the radioactivity would have seriously threatened the lives of 5 to 10% of any persons exposed out of doors for all of the first 36 hr. At a distance of 220 miles or more down-wind, it is unlikely that any deaths would have occurred from radioactivity.

Thus, about 7000 sq. mi. of territory down-wind from the burst was so contaminated that survival might have depended upon prompt evacuation or upon taking shelter and other protective measures.‡

Because the fall-out will vary from point to point, due to variable atmospheric conditions, and because most persons if given sufficient warning, would take precautionary measures, the actual percentage of fatalities could reasonably be presumed to be considerably smaller than these extreme estimates.

Protection — In an area of heavy fall-out the greatest hazard is exposure to *external* radiation, which can be greatly reduced by taking shelter and by simple decontamination. The radiation level indoors on the first floor of an ordinary frame house would be about one-half the level out of doors, and even greater protection would be had in a brick or stone house. Taking shelter in the basement of an average residence would reduce the radiation level to about one-tenth. An old-fashioned cyclone cellar, with a 3-ft. covering of earth, would reduce the radiation level to about 1/5000, *completely safe* in even the most heavily contaminated area. In addition, care should be taken to avoid the use of solid foods or liquids that may contain fall-out particles.

If fall-out particles come into contact with skin, hair, or clothing, prompt decontamination will greatly reduce the danger by such simple measures as a thorough bath and a change of clothing.

Internal Radiation Effects — Radiation is not a new phenomenon. All living things have been exposed constantly to radiation from cosmic rays and "background" radiation from radium and radon in the soil, water and air. Our bodies have always contained naturally radioactive potassium and carbon.

While detonations of all atomic weapons produce radioactivity, the most widespread is only from the longer-lived fission products. They may be distributed over the entire earth, but as the particles are carried to remote areas the possibility of significant amounts of fall-out decreases.

One of the most biologically important is strontium-90. It has a long lifetime — nearly 30 years on the average. It has a chemical similarity to calcium and, when taken into the body, it tends to collect in the bones. Normally, the amount inhaled would be small compared with the amount

*From a statement by Lewis L. Strauss, Chairman, U.S. Atomic Energy Commission, and an accompanying "Report," both released Feb. 15, 1955.

†See *Metal Progress*, March, 1955, p. 90.

‡This is about the size of the state of New Jersey.

one might swallow. Fall-out material deposited directly on edible parts of plants may be eaten, but washing the plants would remove most of it. However, radio-strontium carried down to earth by rain may be taken up by plants and incorporated into plant tissues, later to be eaten by humans, or by grazing animals which in turn provide food for humans.

Since the start of nuclear tests the distribution of radio-strontium has been carefully measured. The amount now present in the soil as a result of *all* nuclear explosions to date would have to be increased many thousand times before any effect on humans would be noticeable.

Radio-iodine-131, with average life of only 11.5 days, is one of the shorter-lived fission products. It concentrates in the thyroid gland. Possibility of serious hazard is limited by its relatively short life. Scientists of the Atomic Energy Commission have estimated that the average exposure of people in the United States from radio-iodine in the fall-out from the entire series of tests in the spring of 1954 was only a few percent of the annual dose that can be received year after year and still have no noticeable effects.

Any accumulation of these dangerous radio-isotopes can be detected with great sensitivity by year-round monitors established in many locations.

Genetic Effects — There is a wide range of admissible opinion as to the genetic effects which radiation might have upon future generations. Data are not available for an incontrovertible forecast. However, the average amount of radiation exposure received by residents of the United States from *all* nuclear detonations to date has been about the same as the exposure received from one chest X-ray. The Atomic Energy Commission's medical and biological advisers do not believe that this small amount of additional exposure is any basis for serious concern at this time.

Fall-out From Nevada Tests — In the relatively small nuclear test explosions at the Nevada test site, as well as in the very large ones in the Pacific, all tests are planned when weather forecasts minimize the fall-out hazard. High air bursts at the Nevada test site have produced no significant fall-out; heavy fall-out from near-surface explosions has extended only a few miles from the point of burst, and is confined to the controlled area. The highest actual dose of radiation at an off-site community has been estimated to be less than one-third of the greatest amount of radiation which atomic energy workers are permitted to receive each year under the Atomic Energy Commission's conservative safety standards.

Conclusion — In the event of war involving the use of atomic weapons, the fall-out from large nuclear bombs exploded on or near the surface of the earth would create serious hazard to civilian populations in large areas outside the target zones.

Book Review...

Science for the Casting Art

*Reviewed by HAROLD J. ROAST**

NON-FERROUS FOUNDRY METALLURGY, Edited by A. J. Murphy; 497 p. McGraw-Hill Book Co., Inc., New York, or Pergamon Press Ltd., London, England. 1954. $12.50.

PROF. A. J. MURPHY is well known as an educator and metallurgical engineer. In addition to serving as editor of the book, he provided the first chapter (preface and introduction), which gives a sound theoretical approach to the topic. Fourteen authorities contribute to the remaining seven chapters.

One third of the book deals with foundry practice as opposed to foundry metallurgy. For example, Garside goes carefully into the question of foundry sands, types of furnaces, and both metallic and nonmetallic molds, and Kondic treats of casting ingots for subsequent working. Garside also describes casting processes including centrifugal and investment casting; useful information is provided concerning patterns and pattern materials. Special reference is made to the use of synthetic resins for making cores and molds, including shell molding and the dielectric heating of cores. Baker, dealing with copper-base alloys, and Hudson, with nickel alloys, also give information on melting and handling of metal.

Lees provides an interesting and useful analysis of the makeup of metal losses. This is followed by a scientific analysis of the oxidation of metal and the losses inherent thereto, and the significance of viscosity, surface tension, and other physical aspects of metal casting. The solution of gases in liquid metals is dealt with from a mathematical viewpoint, and definite information supplied as to the detection and estimation of gases in metal, and – most important of all – their removal. Some 50 pages are devoted to phenomena associated with solidification, and advice is given on the best foundry techniques to insure sound castings.

A discussion of test bars and test objectives is supplemented by informative tables showing the physical properties of copper-base and light alloy castings themselves as compared with the separately cast test bars used for control. The effect of high and low temperatures on castings is treated, as well as the problem of corrosion. Nondestructive testing is described fully, including X-ray and gamma-ray, and the artificially radioactive substances that will be available from atomic piles.

All ordinary nonferrous metals are dealt with in the book, but one misses discussion on the important beryllium-copper alloys, and any advice as to "slush" casting. The increasing importance of the silicon bronzes merits more attention than it receives. (In this connection, Murphy in his introduction speaks of the rather modest values for shock resistance of nonferrous alloys; it is a pity that the Izod figure of 60 ft-lb. for 1.5% silicon bronze is not added to the three examples chosen.)

Much useful data are supplied concerning tin and lead-base alloys, including melting and casting and industrial uses such as bearings and type metal. In the section dealing with babbitting of bearings, reference might have been made to the much simpler method used in North America for

*Bronze Foundry Consultant and Consulting Editor for *Metal Progress*.

lining bronze journal bearings for railroads, where one man produces several hundred bearings a day.

It is refreshing to find considerable data concerning silver, gold, and platinum alloys, which are not generally treated in the few books published on foundry practice.

While many references are made to practices in vogue in North America, it is only natural that the general treatment is British. The book's sound theoretical approach would apply, of course, to any locality.

This book fills a real need, particularly for the aspiring young foundryman who wants to understand the reason why he does many, at first sight, unimportant things. This is particularly necessary in view of the increasing demands being made on the casting industry by engineers, and the competition afforded by welded and other fabricated assemblies.

"Non-Ferrous Foundry Metallurgy" will go far toward securing a sound scientific basis for the ancient art of casting. The editor is to be congratulated on securing a group of well-qualified writers. Many of us have been waiting a long time for this contribution to the foundry library.

A High-Resolution Metallograph for Elevated Temperatures

*By J. E. JENKINS, D. R. BUCHELE and R. A. LONG**

Description of a microscope hot stage and a special objective of reflecting elements with a long working distance and a high numerical aperture to give maximum resolving power. Changes in microstructure are photographed with movie camera.

THIS EQUIPMENT for micrography at elevated temperatures employs a motion-picture camera to record the changes in structure. The specimen, which can be heated to as high as 1800° F. in vacuum or a protective atmosphere, is viewed through a special optical system.

As shown in Fig. 1, the furnace, optical system, camera and accessories are mounted on the optical bench and base of a conventional metallograph. Figure 2 shows the special objective that was designed for use at a relatively great distance (7/16 in.) from the heated specimen. The nu-

*Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics, Cleveland; Mr. Long is now manager, Aircraft Components Div., Ferrotherm Co., Cleveland.

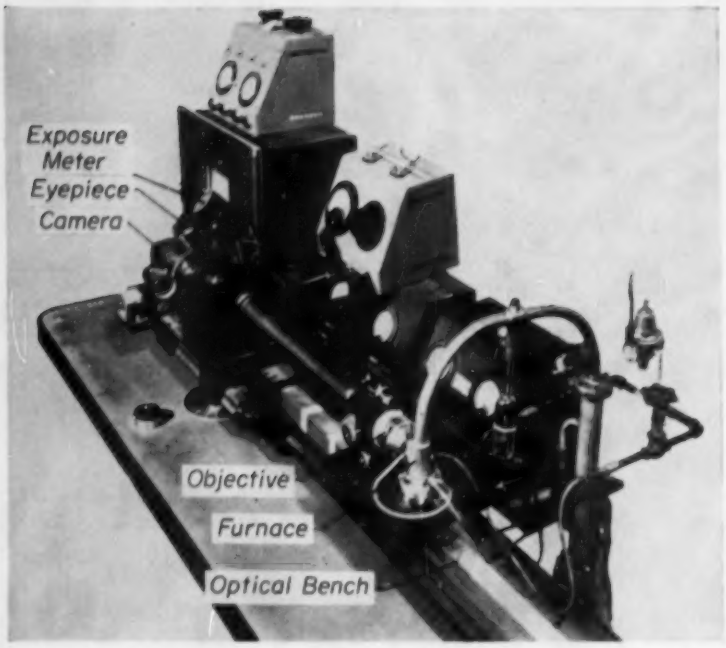
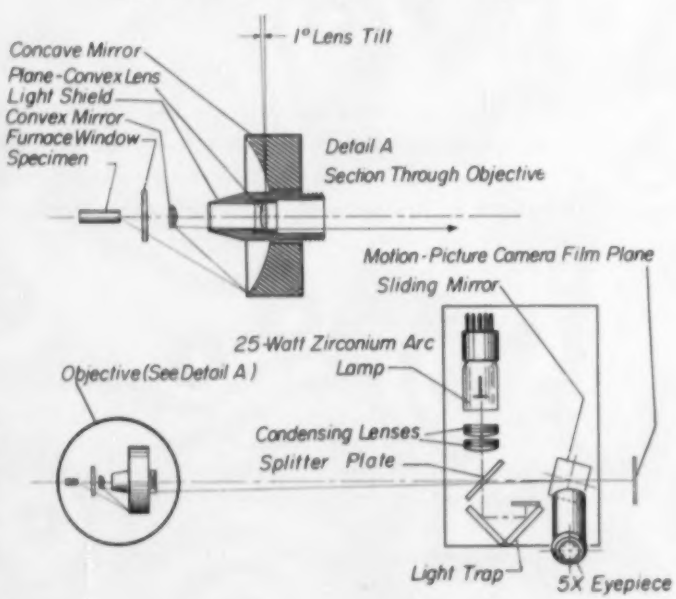


Fig. 1 – Metallograph as Modified for Studies at Elevated Temperatures

merical aperture of this objective is 0.5, thus providing good resolution (0.00002 in. at specimen surface). Also, because of its low chromatic aberration illumination can be in a wide range of wave lengths and the increase in resolution afforded by short wave lengths can be utilized.

The small furnace for heating (shown in Fig. 3) employs no insulating material so as to minimize out-gassing; instead, platinum foil is used as a radiation shield. Heat is conducted to the specimen through a platinum cylinder that also serves as a specimen holder and as a radiation shield to reduce heat loss from the heater element to the furnace chamber walls. A fused quartz window is inserted in the furnace chamber wall between the specimen and the objective. Inert gas, introduced through a fitting in the furnace base, decreases the rate of sublimation of specimens having a high vapor pressure at elevated temperatures. In addition, gas may be introduced that will selectively attack the specimen's microstructure. The top of the furnace chamber is connected to an organic vapor diffusion pump. Temperature of the specimen is controlled by an autotransformer with which the voltage impressed on the heater element is varied.

Fig. 2 – Details of the Special Optical System



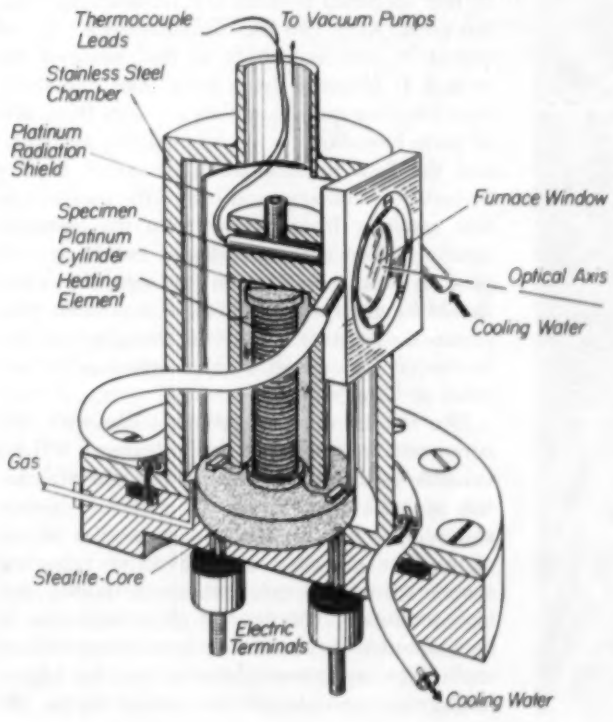
Temperature measurements are made with a pyrometer connected to a thermocouple spot welded to the specimen.

A standard 35-mm. motion picture camera without its lens records the changes in microstructures. An intervalometer controls the intervals exposures by actuating a solenoid attached to the camera shutter release mechanism. The correct exposure is determined by a null-balance exposure meter attached to the eyepiece tube.

A zirconium arc lamp provides illumination through a vertical system similar to those used on standard metallographic microscopes. A second arc lamp and a condensing mirror are for oblique illumination of the specimen.

The microstructure of a specimen of S.A.E. 1035 steel was observed and recorded at temperatures from 80 to 1650° F. The specimen was cut from a ¾-in. diameter bar after it had been furnace cooled from a 30-min. anneal at 1650° F. The specimen was polished, etched with 3% nital and then heated slowly in vacuum in the furnace. Figure 4A shows the structure of this specimen at 80° F. (This series of micrographs was made with a magnification of 100 × on 35-mm. film, and then enlarged to 300 × in printing.)

Fig. 3 — Details of Microscope Hot Stage



The first apparent change in microstructure was observed at 1000° F., Fig. 4B. There was a reduction in contrast and an increase in the relief of the surface and in the apparent sharpness of the image. Evaporation of reaction products of the original etching as well as the increased surface relief of the specimen probably account for the improvement in image quality.

As the temperature was increased to 1200° F., the contrast between the lamellae in the pearlitic grain became less. This trend may be significant. A lamellar pattern was not evident when the specimen was later cooled to room temperature after soaking above the Ac_3 point.

At 1290° F. small spheroids first appeared, these being well dispersed in the ferrite. At 1400° F. the spheroids coalesced and the lamellae of the pearlite disappeared. Fig. 4C. There was a tendency for the spheroids to grow in the ferrite boundaries, in polishing scratches, and around sulphides. Spheroids were also evident in the pearlite grain.

Some austenite grain boundaries became apparent in the former ferrite regions at 1600° F., as shown in Fig. 4D. Most of the ferrite-pearlite grain boundaries continued to etch, although there are portions that have disappeared. The matrix material that was adjacent to the sulphides seems to have evaporated.

At 1650° F., most of the carbides had completely dissolved in the austenite matrix (Fig. 4E) and the austenite grain boundaries had become more prominent. Portions of the previous ferrite-pearlite boundaries have continued to etch, even though they are no longer grain boundaries. It was expected that the grooves formed at the ferrite-pearlite boundary would tend to be filled, or at any rate that they would not increase in depth and width. However, the $\alpha \rightarrow \gamma$ transformation greatly increased the surface relief of the specimen and may account for this apparent trend.

There appears to be a relatively great spread of austenite grain sizes, even though the handbook coarsening temperature for this steel was not reached. Also no tendency for large grains to grow at the expense of small grains was observed. The growth of austenite grains was not observed.

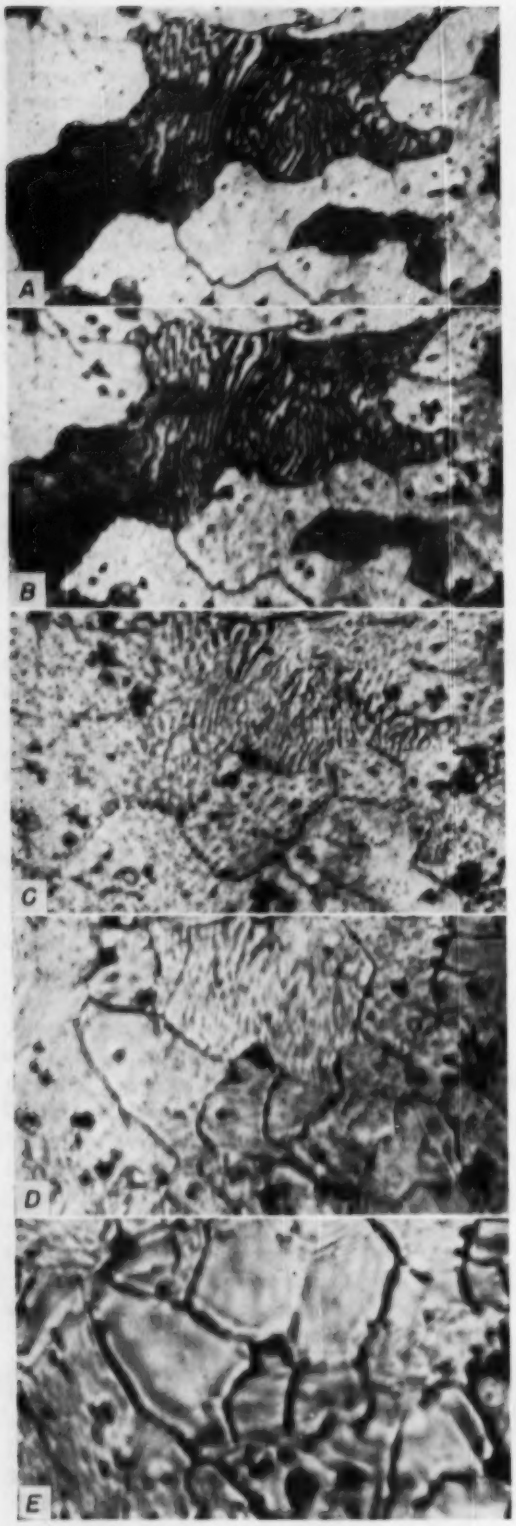


Fig. 4 — Microstructure of S.A.E. 1035 Steel Photographed With Movie Camera at Various Temperatures to Show Resolving Power of Special Optical System. (A) Specimens photographed at 80° F.; (B) at 1000° F. and 18 hr. total heating time; (C) 1400° F. and 21 hr. total heating time; (D) 1600° F. and 27 hr. from start of heating; (E) 1650° F. and 45 hr. from start of heating

The etching in this specimen may be caused by relatively high vapor pressure of the material in and adjacent to the grain boundaries. This phenomenon was observed, as would be expected, at any interruption of the crystal geometry.

The observed structural changes in this steel generally agree with those anticipated. However, the temperature at which these changes occurred is higher than the iron-carbon equilibrium diagram for *pure* iron-carbon alloys would indicate. This discrepancy is probably caused by the rate of heating of the specimen being in excess of that which would give an equilibrium structure at any given temperature, or by effect of incidental impurities in the commercial steel, by thermal hysteresis (lag), or by the specimen's surface being at a different temperature from the thermocouple junction.

Photomicrographs were not made on cooling of this specimen because the surface relief was too great. After two transformations ($\alpha \rightarrow \gamma$ and $\gamma \rightarrow \alpha$) it was impossible to find an area flat enough to obtain a sharp focus. Also, the structure becomes quite complicated with three sets of grain boundaries — the original, the austenitic and the final transformation structure. It may be feasible to observe and record the transformation resulting from cooling from the austenite structure. The specimen should not be etched prior to heating in vacuum, the rate of heating should be great, and the time at maximum temperature should be short. It is thought that this technique may result in a structure with less relief and confusion.

The results of investigations made with this equipment indicate that the instrument will be valuable in the study of aging and recrystallization of high-temperature and refractory metals and alloys, and grain-boundary studies of all alloys. The objective constructed of reflecting elements produces excellent image quality and high resolution. This type of objective seems to be well suited for elevated-temperature metallography. New equipment of similar type but higher resolution is possible with this optical design.

A Microscope Hot Stage

By H. A. SALLER,
R. F. DICKERSON
*and R. J. CARLSON**

A compact unit for studying structural changes in metals at temperatures up to 1800° F. Description covers vacuum furnace, optical group, cold trap and vacuum system.

THE APPARATUS commonly referred to as a microscope "hot stage" has provided investigators with a valuable tool for studying thermal etching, progression of fatigue cracks, recrystallization and other structural changes. The hot stage that is to be described in this article will heat a specimen to 1800° F. in a vacuum of less than 10^{-4} mm. mercury.

Equipment – The hot stage consists of four principal component sections: the furnace, the optical system, the cold trap, and the vacuum pumping group. The furnace section is so arranged that the visual access port for the microscope objective is positioned correctly for a bench-type microscope. A vertical-type metallographic camera is attached to the work table with full vertical movement of camera and bellows.

The cold trap is located directly below the furnace unit, between it and the diffusion pump. This section serves the dual purpose of trapping condensable impurities from the furnace atmosphere and preventing back-diffusion of pump oil vapors. The diffusion pump is attached to the work table. The forepump is placed on the floor and is connected to the diffusion pump by a rubber vacuum hose. Figure 2 shows the assembled hot stage, the arrangement of the various sections, as well as the location of the control panel and vacuum gages.

*H. A. Saller, R. F. Dickerson, and R. J. Carlson are division chief, assistant division chief, and principal metallurgist, respectively, in reactor metallurgy at Battelle Memorial Institute, Columbus, Ohio. This work was done under the sponsorship of the Atomic Energy Commission under Contract W-7405-eng-92.

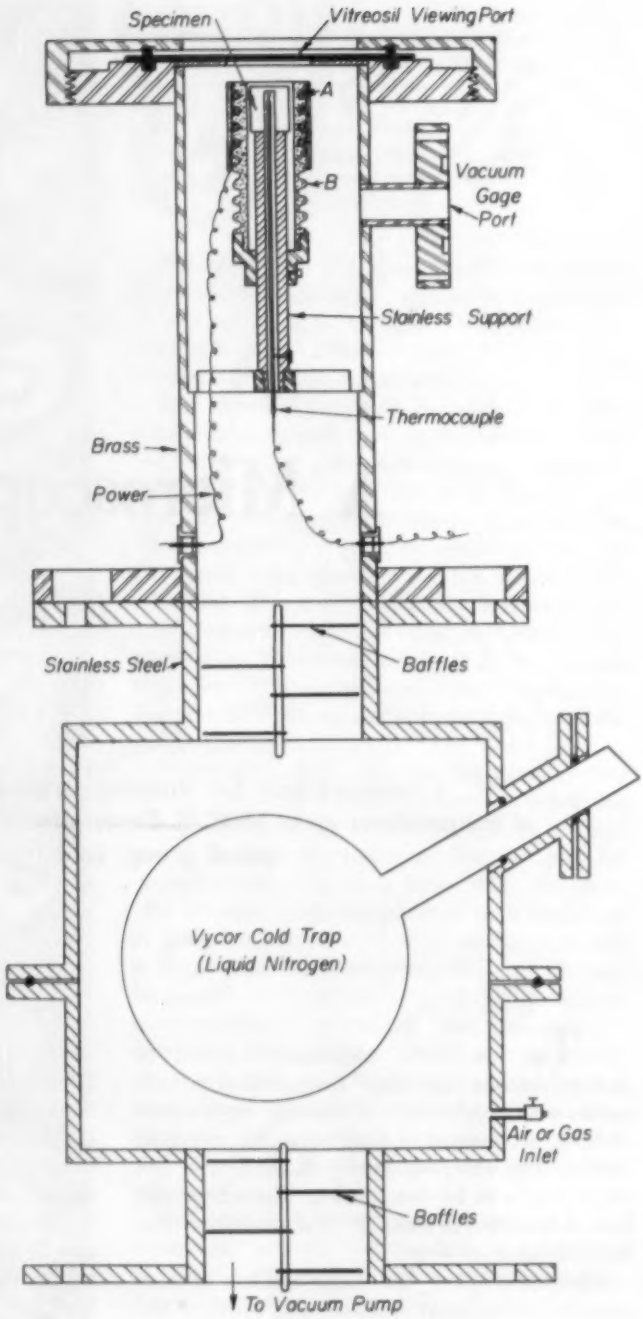


Fig. 1 – Details of Section Containing Furnace in Hot Stage (Top Half) and Cold Trap (Bottom Half). Item A of the furnace is helical molybdenum heater, B is Alundum furnace tube

Furnace – Figure 1 is a schematic drawing of the furnace portion of the apparatus. The brass outer shell of the furnace is water cooled by several turns of copper tubing. A Vitreosil plate, supported by a stainless steel ring, provides visual access to the specimen inside the furnace. The vacuum seal for this port is made by a pair of "O" rings that are set tight by a large screw top.

The resistance heating unit is an Alundum tube wound with molybdenum wire. The specimen is supported in the heating unit on a hollow stainless steel column. The hollow center of the specimen support accommodates the thermocouple for measuring specimen temperatures. Power and thermocouple leads are fed through glass-to-metal seals in the shell walls. Adjustment of the furnace section can be accomplished by set screws which can be used to level the section or move it backward and forward as required.

Optical System – The optical system consists of a bench-type microscope, without stage, a vertical-type camera equipped for use with the microscope, and a ribbon filament illuminating lamp. Photographs can be made with this optical equipment at magnifications of 100, 250, and 500 ×.

No special cooling device has been provided for the objectives, because the visual access port of the stage is in such a position that focus can be obtained while the microscope objective is completely above the furnace. The circulation of free air cools the objectives satisfactorily, provided they are not exposed to the radiant heat from the hot specimen for a long period of time.

Cold Trap – As shown in Fig. 2, the furnace is directly above the diffusion pump. This location is advantageous because of increased pumping speed and compactness of design, but it requires some type of baffle to prevent oil vapors from ascending into the furnace.

The oil vapors have been controlled by the

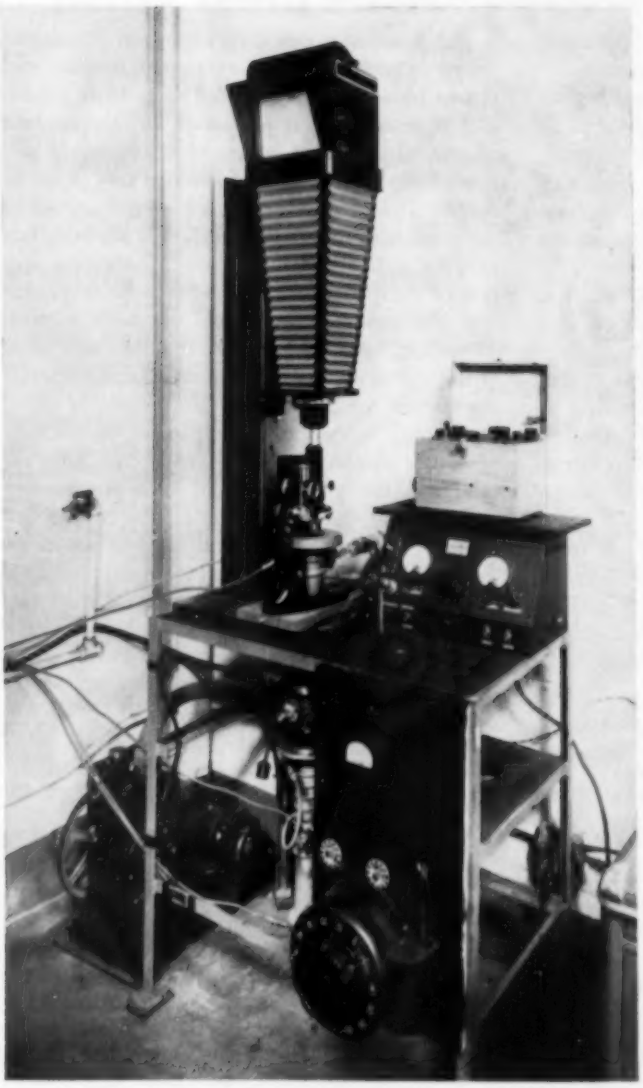


Fig. 2 – Vacuum Hot Stage and Related Equipment Described by the Authors

installation of a liquid-nitrogen cold trap between the diffusion pump and the furnace. This trap gives complete baffling of the oil vapor from the diffusion pump and traps the condensables from the furnace atmosphere with only slight reduction of pumping efficiency.

The shell flanges of this section are constructed of stainless steel. The liquid-nitrogen container is of Vycor. All vacuum seals are "O" rings seated in grooved flanges. An air-inlet valve is located in the shell for the purpose of breaking vacuum or feeding inert gases into the system.

Vacuum Pumps – The vacuum-pumping group consists of a forepump rated at 3.5 cu.ft. per min. of free air displacement and a 2-in. purifying oil-diffusion pump. With the exception of the fore line, the system is entirely of metal.

Pressure is measured during the roughing-down period by a thermocouple-type vacuum gage located on the high-vacuum side of the diffusion pump. Pressures below 10^{-3} mm. of mercury are determined by an ionization-type gage, located in the furnace section as near the specimen as possible. Normal operating pressures for this equipment are about 2×10^{-5} mm.

Operating Procedure

Specimens for study in the hot stage are generally prepared by conventional metallographic techniques. Although certain materials can be etched for examination at temperature, best results are obtained with polished specimens. All specimens must be prepared with top and bottom faces as nearly parallel as possible and be of small enough diameter to fit loosely inside the furnace tube.

After the freshly polished specimens are charged into the stage, the furnace is evacuated, and the temperature of the specimen is then increased gradually by means of an autotransformer. Temperature measurements are made with a potentiometer. It is possible to observe or photograph a specimen at any time after the initial pump-down.

Uses for Research Studies

As this equipment was constructed primarily for use in the examination of uranium at elevated temperatures, most of the results obtained with it have been in that field. However, it has proved to be a valuable metallographic research tool for other materials. An example of such study is the series of micrographs in Fig. 3 showing the thermal-etching characteristics of S.A.E. 1008 steel. The sample was polished and etched in 2% nital solution. Figure 3A is a photomicrograph of

the surface photographed at room temperature. The scattered areas of pearlite are apparent.

The specimen was then repolished and heated in the hot stage to a temperature of 1645° F. as rapidly as possible to insure that a high-temperature structure would be thermally etched, Fig. 3B. There is no evidence of pearlite at this temperature and the structure could be construed as gamma.

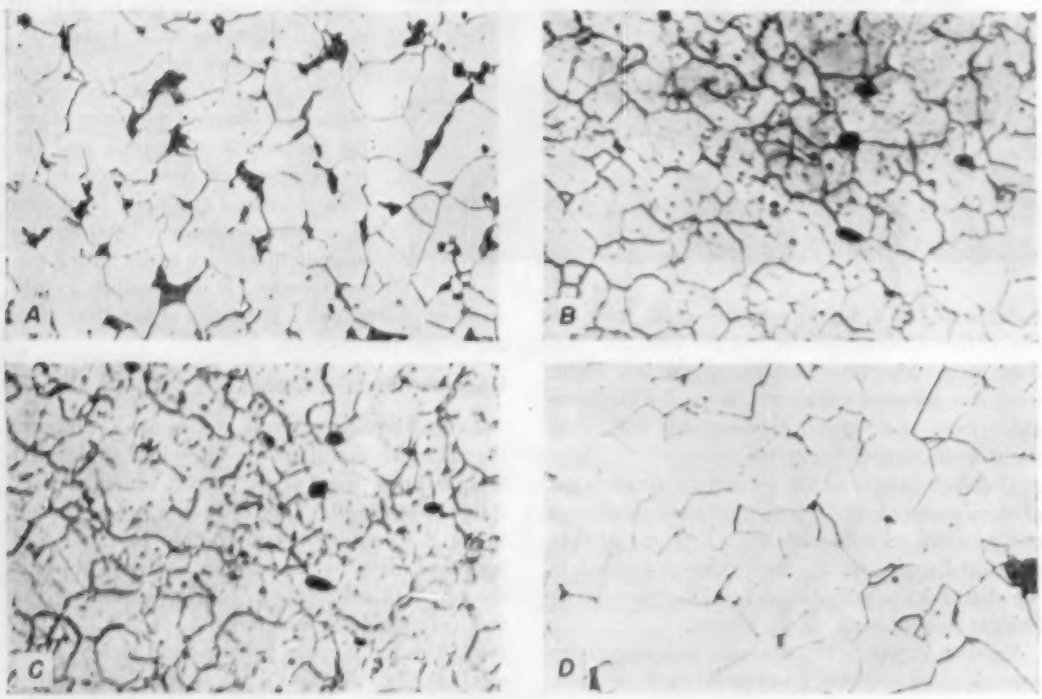
On cooling the specimen to 1350° F., the thermal etch of the higher temperature is still prevalent, but a subtle shift or change in grain boundaries was occurring. A micrograph of the identical field (at Fig. 3B) but after soaking at 1350° F. for 2 hr. is shown in Fig. 3C. Although there is still no evidence of pearlite reappearing, the grains have undergone a pronounced change in shape.

The specimen was then cooled to room temperature, lightly polished, etched with 2% nital, and a typical field was photographed, Fig. 3D. A comparison of this photograph with Fig. 3A shows an apparent reduction in carbon content.

This specimen was then examined at various microdistances below the original surface and it was found that the amount of pearlite gradually increased until it compared with the amount illustrated in Fig. 3A. A complete transverse section of the specimen was examined from edge to center. The outer edges, which were exposed to vacuum, compared with Fig. 3D, with even less pearlite visible at the extremes. The center section of the specimen contained pearlite in quantities which would be normal for such a steel. These findings would indicate that the outer shell of the specimen was decarburized by the operating vacuum of the system.

Although the value of microscopic observation of metals at elevated temperature has been established, the general use of such studies has been limited because of the complexity of the necessary equipment. The microscope hot stage described in this article can be constructed at a minimum of expense, will withstand normal laboratory usage, and can be operated by relatively inexperienced technicians.

Fig. 3 – Micrographs of S.A.E. 1008 Steel Showing Structures Before, During and After Heating to 1645° F., All 250 ×. (A) At room temperature, 2% nital etch; (B) at 1645° F., thermal etch; (C) after cooling to 1350° F. and holding for 2 hr., thermal etch; (D) structure at room temperature after repolishing and etching with 2% nital



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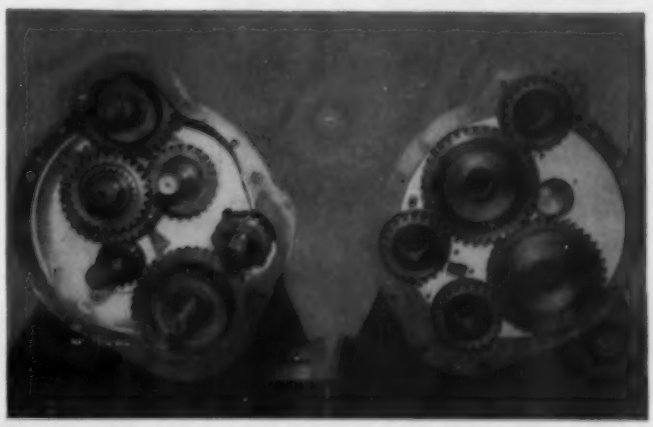

Gears and Pinions of nickel alloyed steel stand the gaff in earth-moving equipment produced by Le Tourneau-Westinghouse Co., Peoria, Ill. The grades of steel used include 3310-H and 4820-H for severe duty, 4320-H for medium heavy service and 8620-H for relatively lighter tooth loads.

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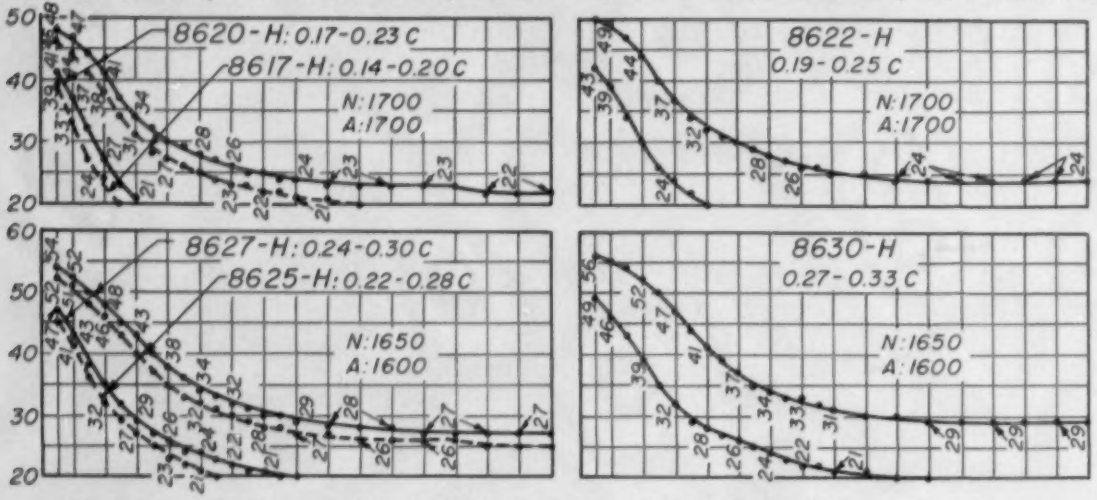
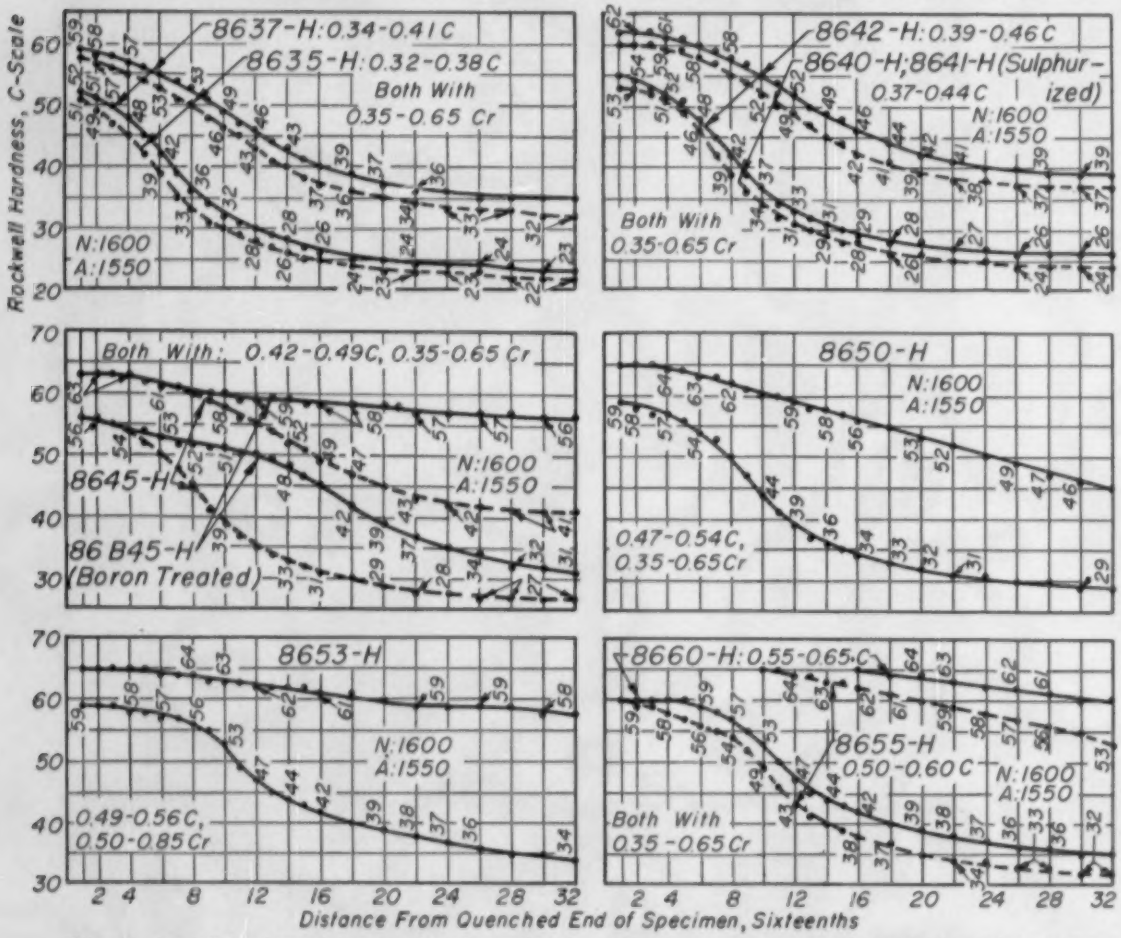
Standard H-Steels, 8617-H to 8660-H

8617-H to 8630-H may contain 0.20-0.35 Si, 0.60-0.95 Mn, 0.35-0.75 Ni, 0.35-0.65 Cr, and 0.15-0.25 Mo



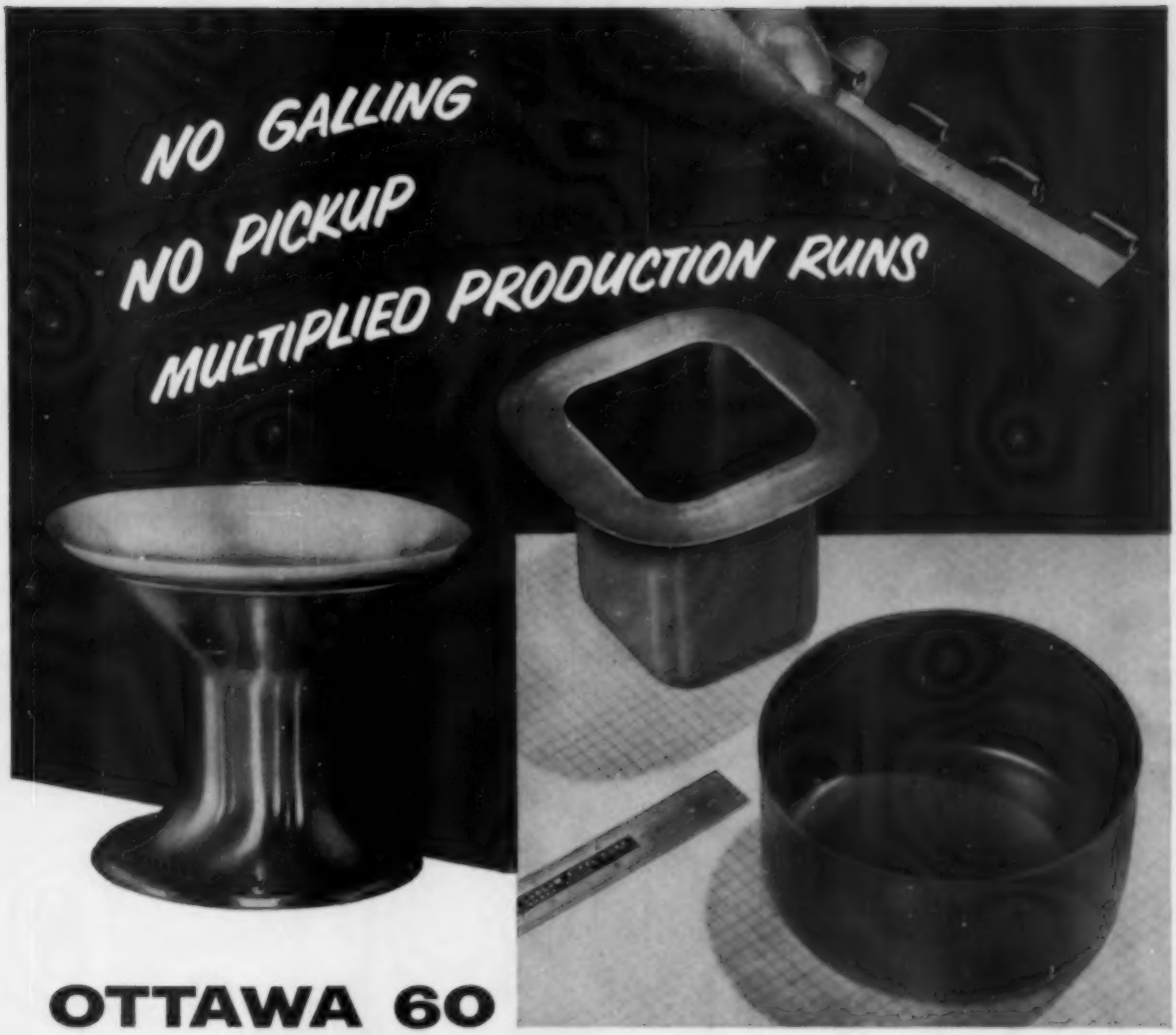
8635-H to 8660-H may contain 0.70-1.05 Mn, 0.20-0.35 Si, 0.35-0.75 Ni, 0.15-0.25 Mo
86B45-H can be expected to have 0.0005% min. boron. 8641-H is high-sulphur, 0.040-0.060 S



N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.).

Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.

A.I.S.I. list of February 1954.



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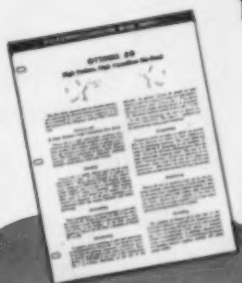

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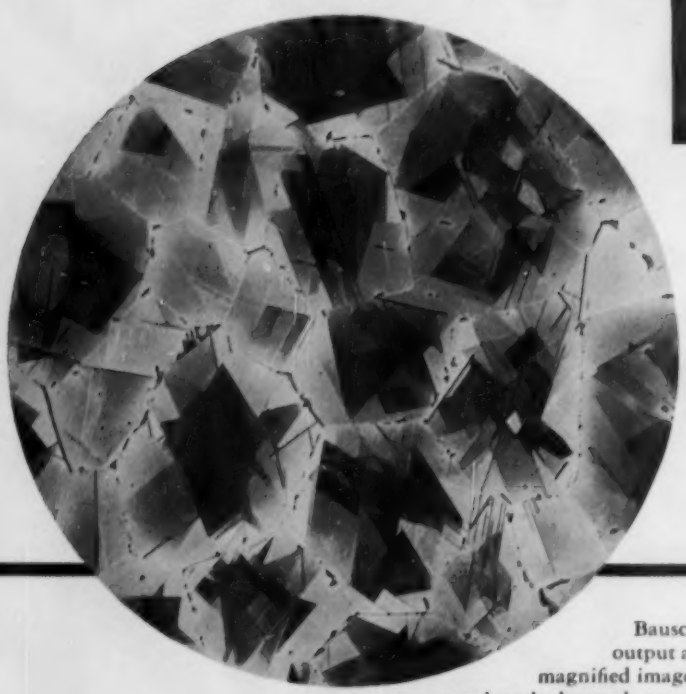

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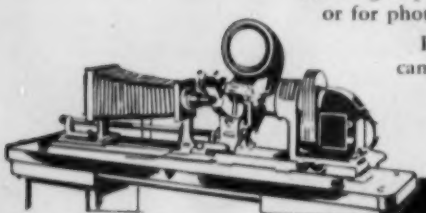

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Welding Cracks in Columbium-Bearing Stainless Steel

Cracks encountered in stabilized stainless steel weldments once plagued the Atomic Energy Commission and its suppliers. Modifications in welding rod and base metal compositions and improved welding techniques have considerably reduced their occurrence.

IN EQUIPMENT used in the various facilities of the Atomic Energy Commission, the fabrication methods, the variety of corrodents, and operating temperatures encountered have required the extensive use of stainless steel not susceptible to intergranular corrosion. For a long time A.I.S.I. Type 347 (columbium-stabilized 18 Cr, 10 Ni) was used almost exclusively and a number of service problems and delays in delivery of equipment were traced to the welding behavior of this alloy. Much of the difficulty has been eliminated through the cooperative efforts of major suppliers to the A.E.C. and its Welding Committee. Recently, a report (Atomic Energy Commission Welding Conference, Sept. 30, 1954, WASH-181) covering its status was partially declassified for the benefit of those who may have similar problems.

Cracking, both in the weld metal and in the heat-affected zone of the base metal, was the major problem for the A.E.C. and for other fabricators and users of Type 347 equipment. Four classes of cracks were reported; the most common was the "crater crack" which had been encountered by all major stainless fabricators queried. This is the kind seen in the crater or surface depression at the end of a weld bead. Next in order of seriousness and frequency of occurrence were "hot short" cracks, or microfissures, in the weld metal; then, base metal cracks; and finally "stress-relief" cracks which appear in either the weld metal or base metal after stress-relieving heat treatment or service at high temperature.

Crater cracks are usually deeper with inert-gas shielded-arc welding than when welding with coated rods. They are attributable in part to the welding technique and can sometimes be eliminated by a controlled decrease of the welding current at the end of the bead which helps fill up the crater. When cracks are obvious, they must be cut out completely and the weld repaired. Even when no cracks are evident, the craters should be removed and refilled if the weld is to be exposed to severe corrodents. There have been installations where severe corrosion has started in such craters and it is not known whether it was associated with undetected cracks or with a difference in corrosion resistance of the weld metal in the crater and the metal in the rest of the bead.

Microfissures, or hot short cracks, in the weld metal seem to be aggravated by columbium in fully austenitic weld metal. The cause is not fully understood and is still under investigation. In America, the accepted method of eliminating or reducing its occurrence is to use a rod that

Crater Crack in Root Pass of Type 347 Weld Metal Deposited in "U" Groove in ¾-In. Type 304 Base Material. 2 ×

will deposit a two-phase structure in the weld metal. From about 4 to 8% ferrite in the structure appears to be the optimum amount for reducing microfissures. Weld metal deposited by lime-coated rods is less susceptible to cracks than that deposited by rods with titania-bearing coatings.

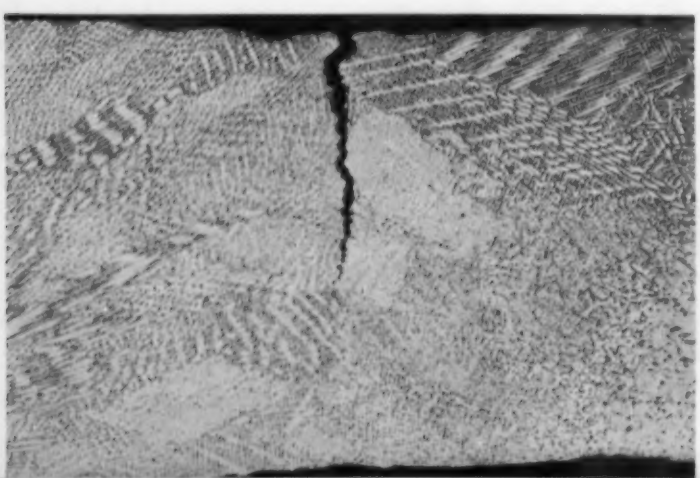
Although it reduces the cracks, the ferrite in the weld metal is not considered ideal for long-time high-temperature applications, since it may transform to sigma and possibly cause a premature brittle failure. In a research program sponsored by the A.E.C., a series of fully austenitic grades that include 19 Cr, 13 Ni, 1 Cb; and 19 Cr, 13 Ni, 5 Mn, 1 Cb is being studied. There is also some evidence that minor or residual elements may affect the fissuring characteristics, so this matter is also being checked. This investigation was initiated by the High Alloys Committee of the Welding Research Council, and has since been under the guidance of an A.E.C. advisory committee. Arcos Corp. is managing the program.

Base-metal cracks are of two general types – those that are a continuation of fissures originating in the weld metal, and those wholly in the heat-affected zone of the base metal. Anything that can be done to reduce stresses during welding will help this condition. If the cracks originate in the weld, they can probably be eliminated by using the kind of rod described above, which produces a two-phase structure in the weld metal. Cracks in the heat-affected zone often indicate something wrong with the composition of the base metal. Sulphur, phosphorus, manganese, silicon, columbium and carbon contents all have some effect on the cracking tendency but the exact relationship is not known.

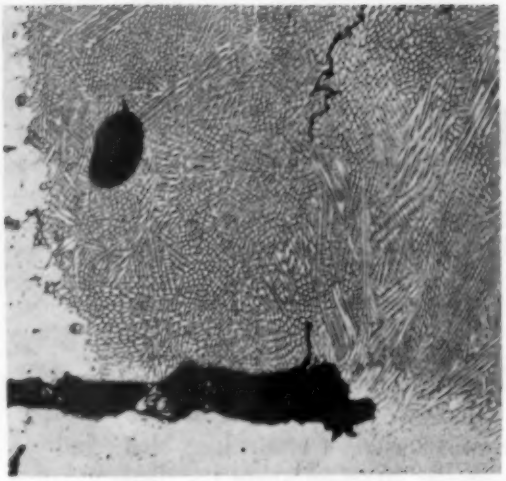
If the cracking cannot be eliminated by reducing the stresses during welding, careful repair welding is necessary, after cutting out the cracked region. Both stress-relieving heat treatment and preheating have been successfully used to eliminate cracks in repair welds. Peening the weld before it has cooled has also proved helpful where a shallow repair is made.

"Stress-relief" cracks, which appear after exposure to heat treatment or elevated-temperature service, are hot tears similar in appearance to microfissures in the weld metal and base-metal cracks. When they are detected in the weld metal, the consensus expressed at this committee meeting is that they were present before exposure but were not detected by the inspector. They either open up slightly during the period at elevated temperatures and become easier to find, or are discovered by more careful inspection.

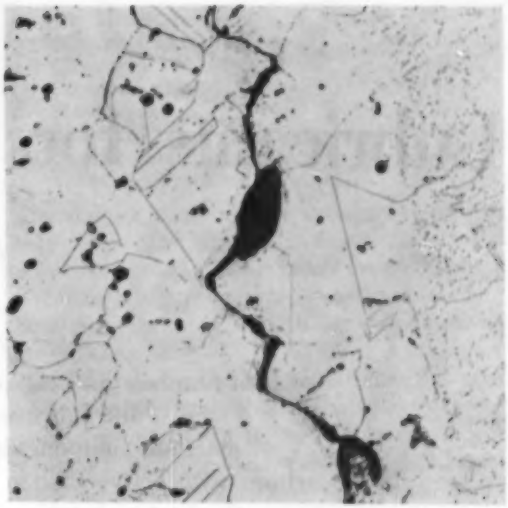
Such cracks in the base metal are often in the same category, that is, overlooked in the first inspection and found later. They can also be attributed to stress-rupture failures when the residual stress in the welded assembly is high. The stress-rupture failure occurs in the base



Hot Short Type of Weld Cracking in 1/16-In. Thick Type 347 Sheet Butt Welded Using the Inert-Arc Process and no Added Filler Metal. Etched with Vilella's Reagent. 50 ×



Microfissures in Low Ferrite Type 347 Weld Deposit at Junction of Back-Up Ring. Oxalic acid etch. 100 ×



Base Metal Cracking in Heat-Affected Zone of Type 347. Etched in Glyceregia. 250 ×

metal because the weld metal is stronger than the base metal at elevated temperature. The remedy is to prevent in some manner high stress conditions in the weldment. Annealing before welding or preheating is one palliative.

In the last four years, Type 304 L (18 Cr, 8 Ni steel with carbon below 0.03%) has served in many applications as an alternate to Type 347. It can generally be used as-welded under ordinary corrosive conditions at temperatures up to 800 or 900° F. Above this range its strength is considerably less than that of Type 347, and there is some question as to its corrosion resistance, particularly where there is a possibility that it might pick up carbon from the surroundings.

In weldments made entirely of 304 L, none of the welding difficulties found with Type 347 have been encountered. There has been some crater cracking but it can be attributed to welding techniques rather than the alloy. For inert-gas shielded-arc welding, Type 308 L (20 Cr, 10 Ni, less than 0.03 C) is used for filler metal. Type 308 L has been used successfully with coated rods, but there is some difficulty in keeping the carbon content in the welds below 0.03%. If the corrosion conditions are so severe that a carbon content of about 0.04% would be harmful, then Type 347 rods must be used and the same problems of crater cracks and microfissures may be encountered as in an all-Type-347 assembly.

Type 308 L weld metal has been used for joints in Type 347 and practically no cracking occurs. It is not generally recommended, however, because dilution of the weld metal by the base metal increases its carbon content which may affect resistance to existing environment. A second disadvantage is that the strength of the weld metal is lower than the base metal and may be insufficient for certain high-temperature or high-stress applications.*

At present when welded assemblies must be made from stainless steel that is resistant to sensitization, the A.E.C. recommends first an all-Type-304 L weldment. If corrosion conditions are severe, 304 L base metal is welded with Type 347 welding rods for extra protection of the weld area. When either operating stress or service temperature is too high for Type 304 L, an all-Type-347 assembly is selected.

To reduce cracks associated with Type 347 weld metal, welding rods that will deposit a two-phase structure with about 4 to 8% ferrite in the austenitic matrix are used. Cracks must be cut out and repaired. Craters should also be eliminated if corrosive conditions are severe.

* In a German steam power plant operating at 1130° F., where a wholly austenitic weld was required, extra-low-carbon unstabilized rods were not used because of corrosion. Instead they have developed and used a columbium-bearing 16 Cr, 13 Ni welding rod composition with a coating containing cobalt. The composition of the weld metal is nominally 0.10% C, 2.5% Mn, 16% Cr, 13% Ni, 6% Co, 1.2% Cb. This development is described in "Successful Manufacture and Use of All-Austenitic Welding Electrodes", by Egon Kanhausen and H. A. Vogels, *Metal Progress*, January 1955, p. 129.

Lubricants for Titanium

By ERNEST RABINOWICZ
*and E. P. KINGSBURY**

Clean titanium rubbing surfaces show high friction and wear, and lubricants which are successful for ordinary machine components are ineffective. Certain long-chain hydrocarbons with active atomic groupings attached along the chain are the best so far discovered; they reduce the coefficient of friction by two thirds, and wear by a factor of ten or more.

AN ARTICLE on the "Frictional Properties of Titanium and Its Alloys" was published in *Metal Progress* for February 1954 (p. 107). It concluded with several observations:

1. When clean surfaces are rubbed together, titanium easily forms strong welds with other metals and comparatively large amounts of titanium are transferred to the other surface.

2. Commercial liquid lubricants, easily adsorbed on other metals, are not effective in reducing the coefficient of friction (0.49) of clean titanium on titanium.

3. Solid lubricants are ineffective because they are weakly bonded to the metal and easily pushed aside.

4. In any sliding combination, the smaller area should be titanium – for example, a titanium piston in a steel cylinder.

The present article summarizes our search for some method of preventing or alleviating the welding and galling characteristics of this interesting metal. Most of the suggested solutions have involved coating the titanium with a solid substance, either one derived from the metal itself (for example, a nitride) or a chemically distinct material that can be made to adhere to titanium and has superior frictional properties (for example, chromium or graphite-resin). All these suffer from the disadvantage that the treatment is not permanent; sooner or later the coating will be worn through and its protection lost. Use of a liquid lubricant, on the other hand, should be free from this objection, and our studies attempted to find one.†

The equipment for measuring the frictional force was described in the article last February. A rider, a ¼-in. rod of RC-70 titanium with spherical end, rested on a rotating titanium flat. Sliding speeds were 2 ft. per min. and the load was 2.2 lb.

In many tests the friction was high for the first few revolutions but gradually dropped off until, finally, a steady value was reached. These circumstances are indicated by the red curve in Fig. 1 representing tests with a single lubricant, Halocarbon 11-14. It was at first thought that this behavior was caused by wear of the hemispherically ended rider, but tests with cylindrically ended riders, in which the geometry remains the same during test, gave the same result. It therefore seems that the drop in friction is associated with the wearing away of the surface layers initially present on the titanium.

*Lubrication Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

† The research on which this paper was based was carried out under contracts No. 53-213 C and 54-390, Bureau of Aeronautics, U. S. Navy. It is with pleasure that the authors thank Prof. Brandon G. Rightmire of the Massachusetts Institute of Technology for encouragement and guidance.

Our numerical conclusions are based on the arithmetical average of the frictional coefficient measured during the first, 26th, 51st, 76th and 101st revolutions. We concluded that such an average was a valid criterion for the effectiveness of the lubricant under test, for the points and curve in black in Fig. 1 made with a variety of lubricants show that in our equipment, low friction between titanium test pieces is always accompanied by low wear. (Wear is measured by weighing both rider and flat before and after sliding 300 ft. at 10 ft. per min. under a load of 5.5 lb., and is figured as grams per centimeter of sliding.)

Mineral Oils – Friction coefficients for titanium lubricated with a considerable number of pure hydrocarbons and commercial mineral oils were measured. Some of the latter contained anti-friction and anti-wear additives. In all, 15 such lubricants were tested; those with viscosity between 50 and 10,000 centistokes were ineffective. With them the friction coefficient of titanium on titanium was 0.45 to 0.47, in comparison with unlubricated friction of 0.49. One oil with even higher viscosity gave a result of 0.41. It appears that mineral oil lubricants are useless.

Long-chain hydrocarbon derivatives were tried on titanium, in view of their effectiveness on other metals, with the following results; the liquids were used pure and the solids in solution in various solvents:

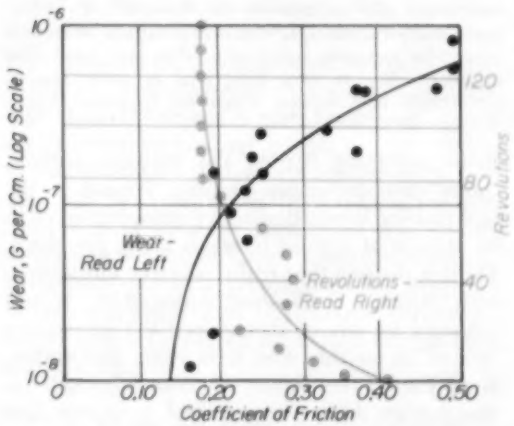


Fig. 1 – Data in Red Show a Gradual Drop in Friction With Increasing Number of Revolutions of Slider Around the Track. These tests were made with one lubricant, Halocarbon 11-14. Black data show that measured amount of wear of titanium against titanium using a variety of lubricants increases directly with the frictional coefficient. Coefficient for unlubricated titanium is 0.49

Lubricant	f
Octadecyl alcohol in cetane	0.40
Oleic acid	0.42
Octadecyl chloride	0.43
Butyl stearate	0.48
n-hexadecylamine in cetane	0.48
Palmitic acid in cetane	0.48
1/16% ferric stearate in an oil	0.53

In addition, a number of commercial greases were tested. The friction coefficient for all was close to 0.49, the value for unlubricated titanium, so that these greases, normally considered among the finest lubricants, had to be abandoned as possibilities.

Reactive Inorganic Liquids – Since the poor lubrication of titanium is probably due to the unusual properties of its surface layers, it was thought that a chemically active liquid might dissolve or otherwise modify the surface layers and produce good lubrication. Among such liquids tried were a strong solution of caustic soda in water, a solution of iodine in alcohol, and a solution of hydrogen sulphide in water. The friction coefficient was lowered slightly, but the rate of reaction with the titanium surface was slow, and the nature of the liquids makes them unsuitable for general use.

No reduction in friction was observed when a solution of potassium nitrite in water was used, although it is effective for grinding titanium. Probably it modifies the titanium surface layers only at high temperatures.

Synthetic Long-Chain Compounds – We tested silicone oils (Dow-Corning Co.); polyethylene glycols, polypropylene glycols and Ucon fluids (Union Carbon & Carbide Corp.); and the Pluronics (Wyandotte Chemical Co.). These latter four compounds contain oxygen atoms periodically inserted into the long carbon chains.

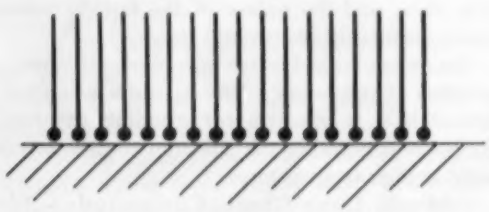
For all of these the initial friction coefficient was similar to unlubricated titanium but decreased as sliding continued over the same track. Within any family of compounds the higher viscosity fluids had the lower friction coefficients, but this effect is not related to the formation of a full-fluid lubricating film, since the friction coefficients were not directly dependent on the sliding velocity. Representative values for a number of compounds, averaged over 100 revolutions, are listed:

Lubricant	f
Polyethylene glycol 1000	0.26
Ucon fluid 25-H-1400	0.31
Polypropylene glycol 1025	0.33
Pluronic L-44	0.36
D-C silicone fluid 200-1000	0.43

While the polyethylene glycols are the most effective, all the compounds do reduce the friction somewhat.

Sugar solutions, molasses, honey, and maple syrup were tried. Fairly low friction coefficients (0.32) were obtained provided the sugar concentration was high enough, but for diluted solutions the values approached 0.49. (The chemical structure of sugar is essentially that of a long hydrocarbon chain with a hydroxyl group substituted on every carbon atom.)

Halogenated hydrocarbons provided good lubrication. The polychloro - trifluoro - ethylenes (made by Halocarbon Products Corp., Hooker Electrochemical Co., and M. W. Kellogg Co.) were particularly effective, and methylene iodide and tribromopropane also gave low friction coefficients. Carbon tetrachloride is relatively ineffective, as are other low boiling-point liquids. Long-chain hydrocarbons with halogen groups on only one or a few carbon atoms also gave high friction coefficients, and it appears that effective lubricants should have every carbon atom or



every other carbon atom halogenated. Trichlorobenzene and other cyclic molecules also had poor lubricating properties.

Lubricant	f
Methylene iodide	0.18
Halocarbon oil 11-14	0.21
S-tetra bromoethane	0.25
1,2,3-tribromopropane	0.27
Carbon tetrachloride	0.34
1,2,4-trichlorobenzene	0.48
1-bromopropane	0.55

Since many of these liquids are very costly, dilute solutions in an inexpensive, inert solvent were tried, such as Halocarbon 11-14 in cetane. It was found, however, that a 30% solution gave a friction coefficient of 0.46, and a 10% solution 0.49 (the same as for pure cetane). Diluted lubricants are apparently impractical.

These results show in a systematic way the unusual difficulties of lubricating titanium. Of great importance is the fact that hydrocarbons are quite ineffective; hence simple mineral oils cannot be used with sliding titanium surfaces.

Next is the curious result that hydrocarbons with an active grouping substituted at one end, as in the long-chain alcohols, acids, soaps, amines, esters and monohalides, are ineffective. Possibly the mechanism of adsorption on other metals, with the active grouping strongly adsorbed to the metal surface and the long chains closely packed at right angles to the surface (Fig. 2, left) does not apply to titanium.

When active atomic groupings are placed at regular intervals along the hydrocarbon chain, however, a better lubricant for titanium is obtained. These active groupings may be halogen atoms, hydroxide groups, oxygen atoms in the chains, and probably other radicals. It seems that when the molecules are adsorbed they lie flat along the metal surface, "stitched down" by the active groupings as visualized in Fig. 2, right hand sketch.

This hypothesis can account for a number of features of the lubricating properties of titanium. First is the fact that ring-shaped molecules (1,2,4-trichlorobenzene) are ineffective, for when

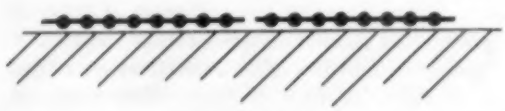


Fig. 2 — Hypothetical Arrangements of Lubricants. Left is for long-chain hydrocarbon derivatives with one reactive end, which is tightly bound to most metal surfaces, forming a dense "carpet." Right represents the adsorption on titanium of hydrocarbon derivatives wherein every carbon atom has a reactive grouping which is held to the metal. The adsorbed film is very thin and is more readily penetrated and broken down by frictional forces

these are lying flat on the titanium surface, "holes" are inevitably present. Second is the fact that for lubrication active groupings have to be present at regular intervals along the chain. Third is the fact that really effective lubrication, with friction coefficients under 0.10, is not achieved by any of them, since the lubricating "carpet" is so thin that it is easily penetrated. Since the friction values of these lubricants on titanium are the same as on steel, it appears that titanium is being lubricated no less effectively than any other metal.

While the drop in friction by the use of these lubricants (from 0.49 to 0.18 or a factor of less than three) may not be too great, the accompanying drop in wear is by a factor of more than ten, and very substantially adds to the life in service of the sliding member.

Hydrogen Embrittlement of Titanium Alloys

Report of an Investigation by
Harris M. Burte, Eugene F. Erbin, George T. Hahn,
*Ralph J. Kotfila, John W. Seeger, and Donald A. Wruck**

Premature failure of aircraft engine parts made of titanium alloy was blamed on high hydrogen content. "Hydrogen embrittlement" has been observed in the laboratory at levels as low as 150 ppm. Producers are changing processes so as to meet Air Force recommendations of 125 ppm. maximum.

By the spring of 1954, work at Battelle Memorial Institute (*Journal of Metals* for March 1954, p. 367) and at Wright Air Development Center (*Metal Progress*, October 1954, p. 128) had indicated that hydrogen contamination might have very bad effects on the performance of titanium and titanium alloys. The seriousness of the problem was emphasized when Pratt and Whitney Aircraft Corp. reported failures of titanium alloy parts which could be attributed to hydrogen embrittlement. Notched specimens taken from the defective parts broke prematurely under sustained loading.

The possibility that contamination by hydrogen had rendered much of the titanium then in service or in stock throughout the country unsuitable for aircraft application prompted an emergency research program at the Materials Laboratory, Directorate of Research, Wright Air Development Center. Of immediate interest were the following:

1. More extensive information on the effects of hydrogen on the mechanical properties of alpha-beta titanium alloys.†
2. Hydrogen tolerances for commercial alpha-beta titanium alloys.
3. The scope of the contamination problem.

The first results of this investigation, originally presented at a meeting at Wright Air Development Center on Oct. 29, 1954, are summarized in this paper.

General Plan of Attack

In order to isolate the effects of hydrogen contamination from other metallurgical variables, it was desirable to obtain different hydrogen contents in specimens from one heat of a given alloy. The hydrogen content was decreased below that of the as-received material by vacuum annealing or increased by heating in a controlled hydrogen atmosphere. Then, to adjust these materials to an equivalent thermal

*First Lieutenants Burte, Erbin, Hahn, Seeger and Wruck are project engineers at the Materials Laboratory, Directorate of Research, Wright Air Development Center. Major Kotfila formerly senior project engineer, is now associated with Rem-Cru Titanium, Inc. The authors wish to acknowledge the assistance of the various members of the Metals Branch, Materials Laboratory, Directorate of Research, WADC, particularly William H. Rector.

†Pure titanium can exist in two crystalline forms – either a hexagonal close-packed structure called alpha, stable below 1625° F., or a body-centered cubic structure called beta, stable above 1625° F. Alloying additions can stabilize the beta phase so it exists at lower temperatures, and most of the commercial alloys contain both the alpha and beta phases at room temperature. See L. D. Jaffe's comprehensive summary of the effects of alloying and heat treatment in *Metal Progress* for February, p. 101.

history, further anneals in air or inert gas were employed. (This does not change the hydrogen content.)

A typical set of treatments applied to a material containing 250 parts per million (250 ppm.) hydrogen as received was:

Final Hydrogen Content, 20 ppm.: Vacuum annealed at 1200° F. for 24 hr.; furnace cooled.

Final Hydrogen Content, 170 ppm.: Vacuum annealed at 1200° F. for 2 hr. and air cooled, then heated in helium at 1200° F. for 22 hr. and furnace cooled.

Final Hydrogen Content, 250 ppm.: Heated in helium at 1200° F. for 24 hr. and furnace cooled (unchanged from the as-received hydrogen content).

Hydrogen analyses were preformed by Battelle Memorial Institute using a vacuum fusion method; values were reproducible within 10%.

Tests—Previous experience shared by Battelle, Pratt and Whitney, and the Materials Laboratory had indicated that in alpha-beta alloys hydrogen could cause embrittlement (fracture with deficient elongation) under slow rate deformation or sustained loading (rupture test). In this investigation tensile tests were performed on unnotched and notched specimens at three strain rates:

Fast—0.1 in. per min. of head travel from yield to fracture (0.003 in. per in. per min. up to yield).

Slow—0.02 in. per min. of head travel from zero load to fracture.

Very Slow—0.005 in. per min.

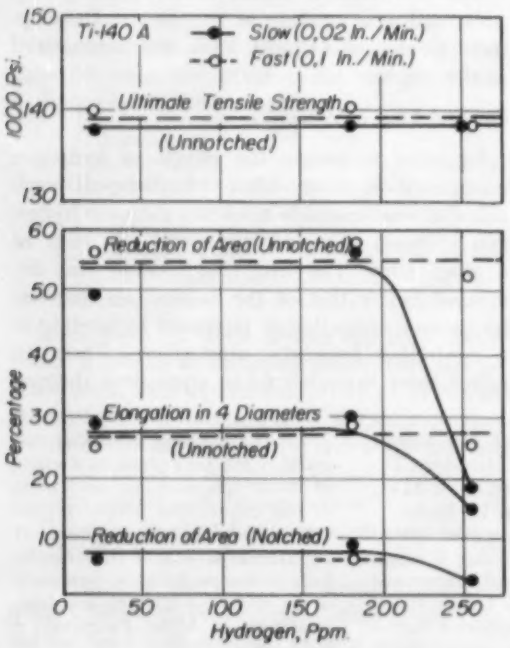
Rupture tests were performed on standard lever-arm creep-rupture frames. In general, several specimens were loaded in tandem on a single frame. When one specimen broke, a new one or a dummy was inserted and the stress reapplied.

The unnotched cylindrical specimens machined from bar stock had a gage length of 1 in. and a gage diameter of 0.187 in. The notched cylindrical specimen was a 0.294-in. bar with a circumferential 60° V-notch that reduced the load-carrying area to a circle 0.187 in. diameter. Radius at root of notch was 0.01 in. Specimen ends for both types were ⅝ in. diameter with 16 threads per inch.

One type of sheet specimen used was a strip ½ in. wide with 60° V-notches from each edge leaving ¼ in. of metal to carry the load. Radius at the root of the notch was 0.01 in. and gage length was 1 in.

It is not suggested that these specimens or test methods are the optimum for this type of testing; they did, however, serve the purposes of an emergency program.

Fig. 1 – Tensile Tests on Ti-140 A at Room Temperature



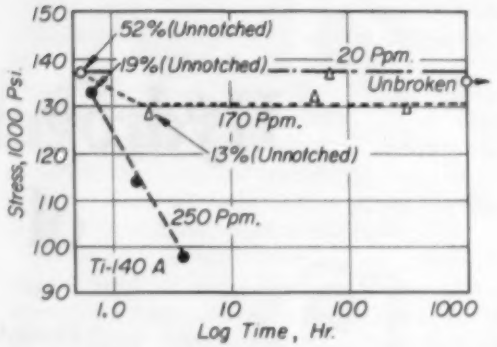


Fig. 2 – Stress-Rupture Tests on Notched Specimens of Ti-140 A at Room Temperature. Three levels of hydrogen contamination are noted: vacuum annealed to 20 ppm. by open circles; 170 ppm. by open triangles; 250 ppm. by black circles. Percentages represent reduction of area at fracture.

Room-Temperature Mechanical Properties

Bar Stock – The results of room-temperature tensile tests are illustrated by the data for Ti-140A alloy (2.26 Fe, 2.35 Cr, 1.76 Mo) presented in Fig. 1. Over the range investigated (20 to 250 ppm.) hydrogen contamination does not affect

the unnotched or notched tensile strengths measured at either the fast (0.1 in. per min.) or the slow (0.02 in. per min.) strain rate. Tensile ductility is affected, but only when measured at slow strain rate.

Rupture tests on this material illustrate the deleterious effects of hydrogen in a much more striking manner. An unnotched specimen containing 250 ppm. fractured in 2.4 hr. at 119,000 psi. (86% of the ultimate tensile strength) with only 3% reduction in area. At this stress level specimens of the vacuum-annealed material (20 ppm.) did not fracture in 1000 hr. Rupture data for notched specimens are shown in Fig. 2. It is evident that:

1. Hydrogen-contaminated specimens can fracture in a brittle manner.

2. Such fractures occur in relatively short times at stress levels where the low-hydrogen material does not fracture in long times.

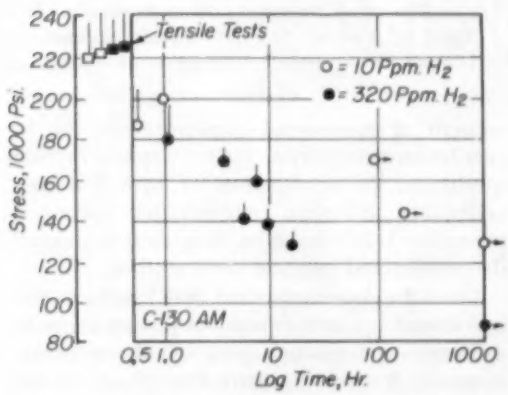


Fig. 3 – Room-Temperature Tensile and Rupture tests on Notched Specimens of C-130 AM. Height of the line rising from each point is proportional to reduction in area at fracture

The data in Fig. 2 for the specimens containing 250 ppm. (solid circles) and 170 ppm. (open triangles) indicate that the time for fracture increases as the hydrogen level decreases. Note that the tensile tests in Fig. 1 on the material containing 170 ppm. did not indicate a loss in ductility at the slow rate of pulling, whereas the rupture test specimens fractured prematurely (Fig. 2). Presumably, the 170-ppm. material would show evidence of embrittlement in a tensile test if an extremely slow rate of straining were used, but as a practical matter it is easier to perform the rupture test.

Similar results were obtained on another commercial forging alloy C-130 AM (5.0 Al, 4.5 Mn). For example, the results of tensile and rupture tests at room temperature on unnotched specimens of this alloy hydrogenated to 320 ppm. are:

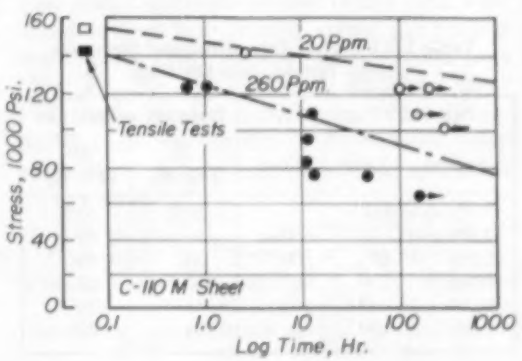
Stress	Time to Fracture	R. A. at Fracture
143,000 Psi.	1.3 hr.	11.8%
136,000	9.0	8.6
129,000	22	5.4
123,000	442	2.6
Fast tensile test	–	39
Slow tensile test	–	37

These data show that ductility decreases as time for fracture increases.

Figure 3 for *notched* specimens illustrates that at very high stresses and short times (up to 1 hr.) there is little difference in the rupture behavior of material hydrogenated (black circles) or vacuum annealed (open circles); both fracture in a relatively ductile manner. However, at low stress levels where low-hydrogen specimens do not fracture, hydrogen-contaminated specimens fracture prematurely in a brittle manner.

Sheet – The effects of hydrogen on the rupture properties of flat specimens from sheet were found to be essentially the same as those observed for cylindrical specimens from bar stock. Some data for C-110M sheet are presented in Fig. 4. It can be seen that high-hydrogen specimens fracture at low stresses, while low-hydrogen specimens have not fractured after much longer periods of time even at higher stresses. Premature fractures are characterized by the formation of a crack at the root of one or both of the notches. These cracks slowly (from 2 to 6 hr.) penetrate the gage section in the plane of maximum tensile stress, progressively reducing the effective cross-sectional area of the specimen. The appearance of the final fracture in the residual cross-sectional area of the specimen is quite

Fig. 4 – Room-Temperature Tensile and Stress-Rupture Tests on C-110 M Sheet. Specimens V-notched both edges



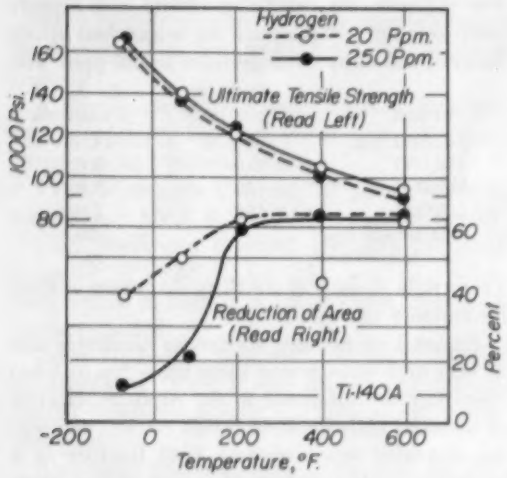


Fig. 5 – Tensile Tests on Unnotched Specimens (Slow Strain Rate) of Ti-140A at Various Temperatures

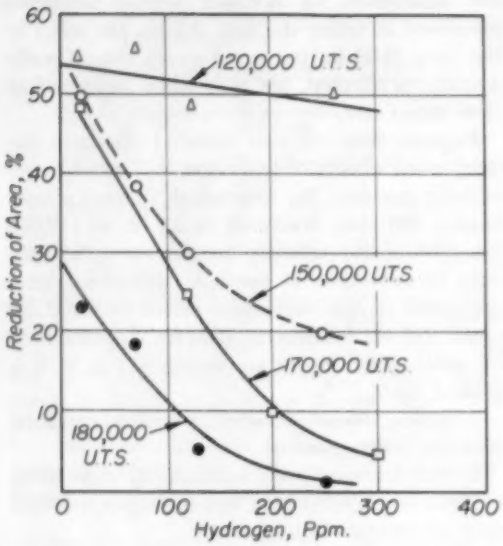


Fig. 6 – Effect of Hydrogen on 3% Mn Complex Alloy Previously Heat Treated and Aged to Various Strength Levels. Tension Tests at 70° F. and at a very slow strain rate

similar to the broken surface in a short-time tensile test. This suggests that *final* fracture occurs simply as a result of overloading.

Unnotched specimens from sheet were unsatisfactory for rupture tests. Hydrogen-contaminated specimens tended to fail in the grip area where stresses concentrate around the pinhole.

Shear cracking of titanium alloy sheet has been a continuing problem. Experiments with titanium alloy sheets over a wide range of hydrogen contents showed no evidence that this is due to hydrogen contamination.

The characteristic effects of hydrogen contamination on the room-temperature mechanical properties of alpha-beta alloys are, then, the strain rate dependence of tensile ductility and premature brittle fracture in rupture tests. It is interesting to note that these effects are similar to the effects of hydrogen on steel. In any event, the most significant consequence of this hydrogen embrittlement is that the load-carrying capacity of commercial titanium alloys can be very seriously impaired. For the notched rupture specimens, the combination of hydrogen contamination and stress concentration can cause premature brittle fractures at quite low nominal stresses (figured on gross cross section).

Table I – Effect of Prior Heat and Stress on Room-Temperature Ductility

Previous Treatment			Reduction of Area	
Stress	Temp.	Time	20 ppm. H_2	250 ppm. H_2
As annealed			56%	55%
95,000 psi.	70° F.	500 hr.	56	49
80,000	200	100	55	43
80,000	200	500	55	27
50,000	600	100	51	30
50,000	600	500	54	37

The data also emphasized that hydrogen embrittlement is a time-dependent phenomenon. In hydrogen-contaminated specimens the reduction in area at fracture decreases throughout the following progression, ranging from short-time to long-time tests:

Ductile End

Fast tensile test
Slow tensile test
High-stress, relatively short-time rupture test
Low-stress, long-time rupture test

Brittle End

Furthermore, the time required for embrittlement appears to increase as the hydrogen *level* decreases. Since this hydrogen embrittlement is so time-dependent, the shorter-time tests may not differentiate between hydrogen-free and hydrogen-contaminated material.

It should be noted that these effects of hydrogen on the mechanical properties of alpha-beta alloys are quite different from the effects on alpha alloys. In alpha alloys embrittlement is observed when notched specimens are tested at high strain rates. See the article in *Journal of Metals*, March 1954, noted at the beginning.

Figure 5 shows the effects of temperature on the slow-strain-rate, unnotched tensile properties of both hydrogen-contaminated and vacuum-annealed (low-hydrogen) Ti-140A. At 70° F. hydrogen-contaminated specimens exhibit lower ductilities (reduction of area) than vacuum-annealed specimens. However, this difference diminishes with increasing temperatures; above 200° F. hydrogen contamination appears to have no effect on reduction of area. Ultimate tensile strength is little affected by hydrogen content, at least in the range of 20 to 250 ppm. Furthermore, at 200° F. the hydrogen-contaminated material shows no tendency for premature fracture at a stress level which does cause premature fracture at room temperature. Rupture test data for notched specimens at 72 and 200° F. are:

Hydrogen Level	Temperature	Stress	Time
20 ppm.	72° F.	100,000 psi.	>1224 hr.
	200	111,000	>1175
250 ppm.	72	98,000	4
	200	111,000	>917

The effect on room-temperature properties of exposure to stress at elevated temperatures was also determined. Results of these tests on Ti-140A, in terms of reduction of area of specimens tested in tension at room temperature subsequent to exposure, are shown in Table I. It should be noted that the tensile tests were performed at the fast strain rate and that all the specimens tested were originally in an annealed condition. The low-hydrogen material had been vacuum annealed at 1200° F. for 24 hr.; the high-hydrogen was treated similarly in helium.

The results show unmistakenly that exposure to stress and temperature leads to embrittlement (brittle-type fractures) in the hydrogen-contaminated materials, but has little effect on the vacuum-annealed material. Since the fast rate of deformation in the tensile test used does not offer sufficient time for embrittlement, the loss in ductility noted for the hydrogen-contaminated specimens must have occurred during the prior exposure to high temperature and stress.

Whereas the results of tensile and rupture tests conducted at elevated temperatures suggest that the deleterious effects of hydrogen are confined to temperatures below 200° F., the data in the table show that hydrogen continues to influence the properties of Ti-140A at temperatures as high as 600° F. It is not yet known whether the amount of hydrogen required to cause this elevated-temperature embrittlement is more or less than the amount required to cause the type of embrittlement noted in room-temperature rupture testing.

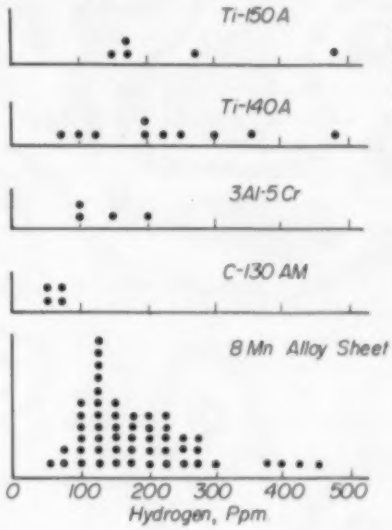


Fig. 7 – Frequency distribution of Hydrogen Analyses of Various Alloys in the Hands of Air Force Contractors in 1954

Effect of Heat Treatment

In order to determine whether an age hardening treatment would affect the ductility of samples containing various amounts of hydrogen, some tensile samples were prepared of the 3% manganese complex alloy (*Metal Progress*, October, 1954, p. 128). These were at four hydrogen levels (approximately 30, 120, 200 and 300 ppm.) and each set was heat treated to four strength levels (120,000; 150,000; 170,000 and 180,00 psi.) by appropriate aging after solution treatment.

These samples were then pulled at a very slow strain rate. Resulting figures for reduction in area are plotted in Fig. 6. It is obvious that hydrogen has a more pronounced detrimental effect at the high strength levels than at the 120,000-psi. strength level. The high-strength material shows evidence for embrittlement at hydrogen levels as low as 100 ppm.

In another experiment, specimens of Ti-140A alloy with a hydrogen content of 210 ppm. were tested in two heat treated states: *(a)* furnace cooled from 1200° F., and *(b)* air cooled from 1350° F. The furnace-cooled specimens show evidence for premature fracture whereas the air-cooled specimens do not. The results of room-temperature rupture tests on notched specimens are as follows:

Heat Treated Condition	Stress	Time to Fracture
Furnace cooled	175,000 psi.	1.0 hr.
	145,000	4.0
Air cooled	170,000	>93
	145,000	>300

The results described above suggest that the susceptibility to hydrogen embrittlement, or the hydrogen content at which embrittling effects first become noticeable in alpha-beta alloys, depends upon the prior heat treatment or upon the microstructure.

Hydrogen Tolerances

In order to obtain information on the levels of hydrogen contamination which can cause embrittlement, some of the commercially available forging alloys were subjected to room-temperature rupture tests. In general, one or more high-hydrogen levels for a given heat were compared to a vacuum-annealed low-hydrogen control lot presumed to be free of hydrogen embrittlement. Premature fracture of the high-hydrogen material was accepted as evidence of embrittlement. The results of these tests are summarized in Table II.

These results show that embrittlement can occur at hydrogen levels as low as 150 ppm. It is not known how closely the vacuum-annealed level must be approached before ductile behavior is attained, since no data were obtained in these investigations about behavior of metal containing hydrogen levels between the lowest ones shown and the low levels of the control lots.

Table II – Evidence of Embrittlement as Indicated by Stress-Rupture Test

Alloy and Heat	Hydrogen Level	Brittleness?
Ti-140 A (2 Fe, 2 Cr, 2 Mo)		
Ht. M 1170	170 ppm.	yes
Ht. M 1170	250	yes
Ht. M 1192	210	yes
Ti-150 A (1.5 Fe, 2.7 Cr)		
Ht. R 68	250	yes
Ht. M 308	160	yes
Ti-155 AX (5 Al, 1.4 Fe, 1.4 Cr, 1.2 Mo)	260	no
C-130 AM (4 Al, 4 Mn)		
Ht. B 5038	320	yes
Ht. B 3371	150	yes
Ht. B 3371	190	yes
Ht. B 3371	280	yes
Ti-6 Al-4 V (6 Al, 4 V)	270	no

The Ti-155AX and Ti-6A1-4V alloys showed no evidence of embrittlement due to hydrogen but since only one heat and one heat treated state was tested, there is not yet enough information to justify high hydrogen tolerances for these compositions. The results do, however, suggest that it should be possible to produce alpha-beta alloys with high hydrogen tolerances.

Scope of the Contamination Problem

Some of the possible sources of hydrogen contamination in titanium alloys are:

1. Acid leaching of sponge.
2. Carryover of water into the arc melting operation.
3. Pickling or descaling operations.
4. Annealing or heat treatment in the presence of water vapor or a reducing atmosphere.

A survey of titanium alloy stock being used by Air Force airframe and engine contractors during the summer of 1954 showed that the hydrogen content of samples from different heats ranged from about 50 to more than 400 ppm. A breakdown by alloys is shown in Fig. 7; each point represents a different heat.

The titanium currently being produced may have much less hydrogen than the material on hand in mid-54, since the manufacturers have modified their processes in an attempt to control hydrogen content. These include reduced pressure arc melting, double melting, improved pickling baths, and the use of oxidizing atmospheres for annealing or heat treatment. In addition, contaminated material is being reclaimed by vacuum annealing.

More information is needed on the effects of sponge hardness, alloy composition, and heat treatment on the hydrogen tolerances for titanium materials. For the present, the Air Force has recommended a maximum hydrogen content of 125 ppm. in aircraft-quality alpha-beta titanium forging alloys, as shown in Specification Bulletin 108.

Summary

Hydrogen contamination in alpha-beta titanium alloys can cause low ductility in slow-strain-rate, room-temperature tensile tests and premature brittle fracture in room-temperature rupture tests. Combination of stress concentrations and hydrogen contamination can lead to a drastic decrease in the load-carrying capacity of these alloys. Another result of hydrogen contamination is increased susceptibility to embrittlement as a result of exposure to stress and elevated temperature.

The hydrogen level at which embrittlement becomes noticeable depends upon alloy composition and heat treatment. Premature brittle fracture in room-temperature rupture tests has been noted with hydrogen as low as 150 ppm.

32 pages; 92 pictures and sketches

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Personal Mention

John F. Tyrrell

In line with *Metal Progress*'s expanding editorial program, a new associate editor has been appointed. John Tyrell ⓜ brings to the staff a unique combination of qualifications —metallurgical engineering and business knowledge concerning our publication acquired by serving as sales respresentative.

John Tyrrell graduated from Massachusetts Institute of Technology in February 1943 with a Bachelor's degree in metallurgy. His first position was with Allegheny Ludlum Steel Corp., where he worked principally on mill problems associated with stainless steels. After a two-year interruption for naval duty, he joined the Solar Aircraft Co. of San Diego, Calif. as a metallurgist. His experience here in the fabrication of aircraft and jet-engine alloys ranged through the welding, forming, heat treating and cleaning departments and the stainless steel foundry; he also assisted in the development of new alloys for gas turbines.

Tyrrell joined the business staff of *Metal Progress* in 1951, covering part of the eastern territory. On the editorial staff he will work closely with John Parina, Jr., an associate editor since 1951, under the direction of Ernest E. Thum, editor of *Metal Progress* since it was established by A.S.M. in 1930.

WILLIAM H. EISENMAN,
Secretary
American Society for Metals

Bruce S. Old

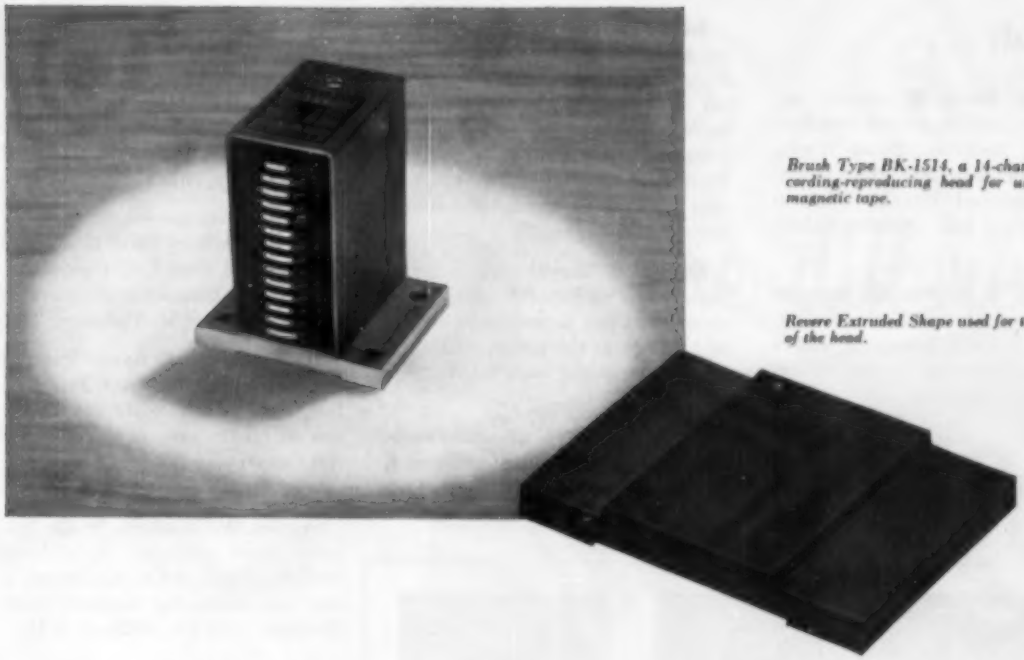
BRUCE S. OLD ⓜ, formerly president of Cambridge Corp., Cambridge, Mass., and more recently chairman of the board, has resumed his full-time activities as vice-president in charge of the chemical and metallurgical engineering division of Arthur D. Little, Inc. Dr. Old graduated from the University of North Carolina with a B.S. degree in chemical engineering, and received his Sc.D. in metallurgy from Massachusetts Institute of Technology. For several years following graduation, he was research engineer for Bethlehem Steel Co., and later joined the Office of Coordination of Research and Development, going from there to the Office of Research and Inventions in the Office of the Secretary of the Navy.

He left the Navy with the rank of commander, and joined Arthur D. Little, Inc., in 1946. Here he directed research on the operation of iron blast furnaces at high top pressure, and was also responsible for the development of the jet tapper, now used extensively by the steel industry in this country for safely and economically tapping open-hearth furnaces. Dr. Old has recently resigned as consultant to the Atomic Energy Commission, where he was chief of the Metallurgy and Materials Branch, Division of Research. He is also a member of the American Institute of Mining and Metallurgical Engineers.

Walter A. Dean

Walter A. Dean ⓜ, chief metallurgist of Aluminum Co. of America's Cleveland Works, has been named co-ordinator of technological developments in titanium. This is in line with the company's expanding titanium activities, particularly in the forging field. Dr. Dean has been active in research and process metallurgy with Alcoa for the past 25 years, and was prominent in the development of a number of aluminum alloys. A native of Bridgeport, Conn., he graduated from Cooper Union Institute of Technology in 1926 with a B.S. degree in chemical engineering. He continued his studies at Rensselaer Polytechnic Institute, where he received his M S. degree in 1927 and a Ph.D. in 1929. Following this, he went with the research laboratories of Aluminum Co. of America at New Kensington, Pa. In 1931 he was transferred to the research laboratories in Cleveland, where he remained until promoted to assistant manager of the permanent mold plant in 1945. In 1949 he became chief metallurgist of the Cleveland Works. Dr. Dean has written several articles on machinability of aluminum, and is the author or co-author of approximately 90 patents covering alloy and process developments. He is a past chairman of the Institute of Metals Division of the A.I.M.E.

Charles J. McGowan ⓜ has been appointed sales engineer for the Pittsburgh territory for Standard Steel Works Div., Baldwin-Lima Hamilton Corp., Pittsburgh. Mr. Gowan formerly represented Kropp Forge Co., Chicago.



Brush Type BK-1514, a 14-channel recording-reproducing head for use with magnetic tape.

Revere Extruded Shape used for the base of the head.

Revere Extruded Shape

Saves 15¢ per piece

For Brush

The base of the magnetic recording-reproducing head shown here is a Revere brass extruded shape. You can see that it is rather simple in design, yet Brush Electronics Co., Cleveland, Ohio, reports that the shape saves 15¢ per piece (1½" long) over the previous method of milling the piece out of solid bar. There were three operations required on the bar, which weighed 1.61 lb. per foot, against 1.22 lb. per foot for the shape. Eliminating the machining operations, and reducing scrap almost to the vanishing point, produced the economy.

The head in question can record and reproduce signals from 14 channels, at frequencies within, below, or above the audible range. Such a head is being increasingly employed to handle information to be used for computation, telemetering, inventory records, process control (automation) and similar purposes.

Extruded shapes by Revere should be looked into if you are doing any extensive machining of raw stock in copper and its alloys, and aluminum alloys. The extrusion process is much like squeezing paste from a tube. Much more intricate shapes than the one shown here are possible. Naturally, all design lines must be parallel to the axis of extrusion. Get in touch with the nearest Revere Sales Office, and see if Revere Extruded Shapes may not save you money.

REVERE

COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

230 Park Avenue, New York 17, N. Y.

• • •

Mills: Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y.— Sales Offices in Principal Cities, Distributors Everywhere.

SEE "MEET THE PRESS" ON NBC TELEVISION, SUNDAYS

Personals . . .

Moss V. Davis recently accepted the position of chief metallurgist with Anderson Brass Works, Inc., Birmingham, Ala. He was formerly employed by the Western Electric Co., Inc., Winston-Salem, N. C.

Malcolm F. Judkins, manager of new products for Firth Sterling, Inc., was recently presented with a lifetime membership in the Society of Carbide Engineers.

John H. Zauner was recently appointed general manager of Henry L. Crowley & Co., Inc., West Orange, N. J.

Gilbert E. Kempka, previously an instructor in the department of metallurgical engineering, University of Wisconsin, and more recently project assistant on malleable iron research, American Foundrymen's Society, at the same university, is now chief metallurgist for Johnson Motors, Waukegan, Ill.

Kenneth E. Shaweker, formerly metallurgist for Republic Steel Corp., Massillon, Ohio, is now employed as an attorney in the patent section of Battelle Memorial Institute, Columbus, Ohio.

T. E. Rybka is now sales engineer in the special products division of the American Cast Iron Pipe Co., Birmingham, Ala.

Alfred S. Keh, who has completed his work toward his Ph.D. degree in metallurgical engineering at the University of Michigan, has joined the Fundamental Research Laboratory of United States Steel Corp., Kearny, N.J.

Floyd S. Greenwood, Jr., is on a two-year military leave of absence from Lukens Steel Co., Coatesville, Pa., and is in training as an ordnance supply specialist at Aberdeen, Md.

H. T. Gibbons has resigned as chief inspector at Airtex Products, Inc., Fairfield, Ill., to accept a position as quality control director and chief inspector for A. B. Chance Co., Centralia, Mo.

Stanley W. Moulton, Jr., formerly chief engineer at Midwest Precision Castings Co., Cleveland, is now an estimating engineer with Hitchiner Mfg. Co., Milford, N.H.

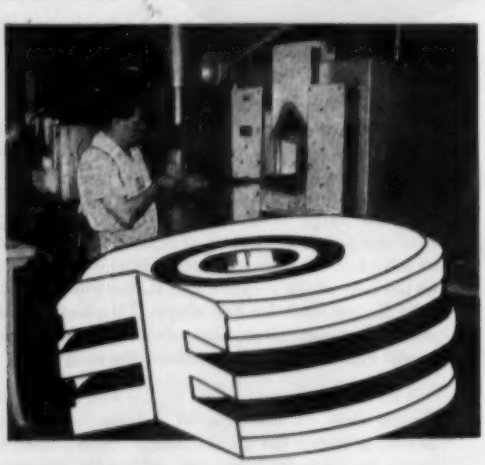
Norbert D. Greene, Jr. has received his M.S. degree in metallurgy from Ohio State University and is now working toward a Ph.D., specializing in corrosion research, under sponsorship of the Alloy Casting Institute.

Dante Accinno, formerly research associate at Stevens Institute of Technology, is now a metallurgist in the physical research laboratory, Baker & Co., Inc., Newark, N.J.

James B. Reid was recently appointed magnesium sales supervisor in the Philadelphia sales office of Dow Chemical Co. after working for 13 years in the New York sales office. He has been with Dow 25 years.

Frank L. Whitney, Jr., corrosion consultant for the general engineering department of Monsanto Chemical Co., St. Louis, has been elected president of the National Association of Corrosion Engineers.

Donald L. LaVelle, formerly research metallurgist in the central research laboratory of the American Smelting and Refining Co., New York, has been appointed assistant manager of the aluminum department and will be located at the company's Perth Amboy, N. J., plant. Mr. LaVelle graduated from the University of Washington in 1941 and Montana School of Mines in 1942 with B.S. and M.S. degrees in metallurgical engineering.



Sentry Furnaces Mean
***Reliable* Heat Treating**

If you are looking for complete protection against scale and decarburization on your high speed and air hardening steel tools during the heat treating cycle — Sentry Equipment belongs in your Heat Treating Department.

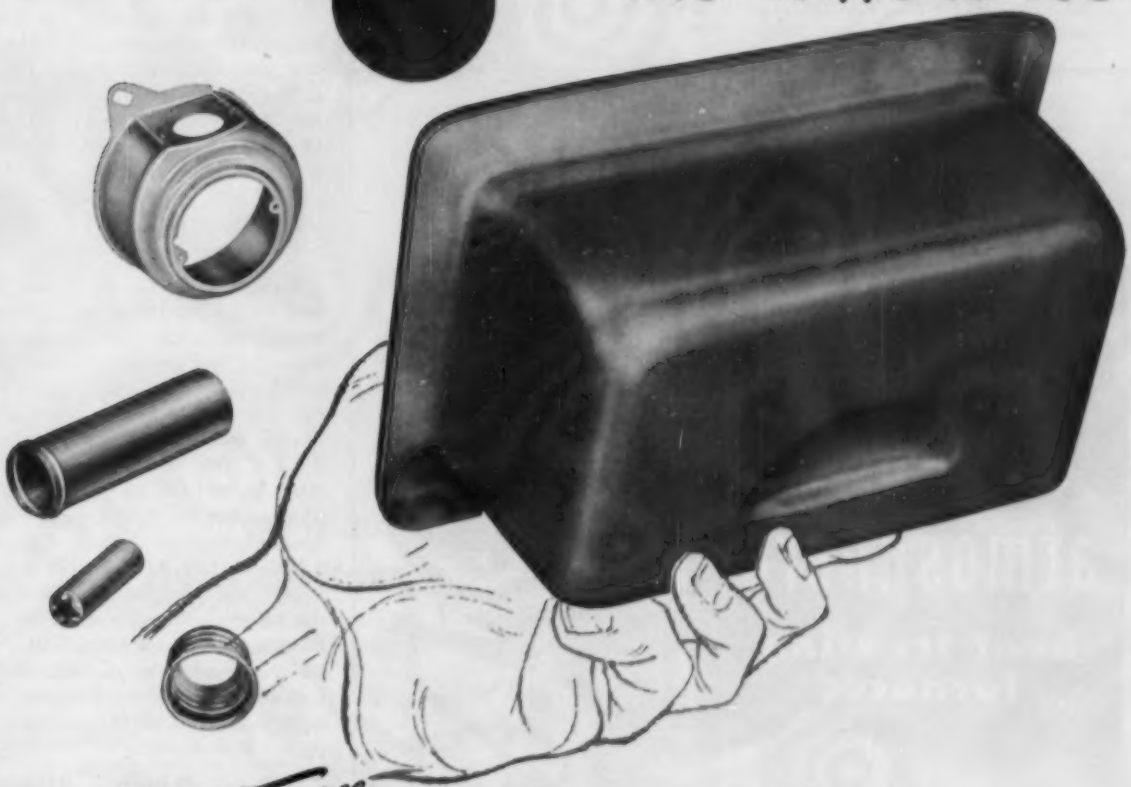
Sentry's claim to reliability, economy and quality is well founded on years of satisfactory performance in leading metal-working plants throughout this country and abroad. In Sentry Furnaces important tools may be hardened with confidence, completely free from scale or decarburization while amply soaked to assure maximum hardness.

If you are heat-treating circular form tools, counter bores, taps, drills, dies, cutting tools — in fact any tools made from high speed or air hardening steels — get the facts on Sentry Equipment. It belongs in every Heat Treating Department.

Request Catalog F-36
Tells the full story of Sentry Furnaces and The Sentry Diamond Block Method.

Sentry ELECTRIC FURNACES
THE SENTRY CO. · FOXBORO · MASS.

You can sell the difference



SCOVILL *Truspec* ALUMINUM . . .

is an exclusive development that exemplifies what we mean when we stress the salable difference in Scovill Mill Products.

Here is aluminum that sets a new standard of uniformity in meeting close specifications . . . in precision control of directional properties, temper and grain size . . . in close dimensional limits and fine finish . . . features that mark a distinct difference in commercial wrought aluminum sheet alloys.

The above photograph of typical parts demonstrates the fine fabricating qualities of Truspec . . . that make it possible for you to control "earing" and "orange peel" effect to a far greater degree than has been possible in the past.

As a result, products made from Truspec Aluminum show superior quality and finish, with fewer rejects at maximum production . . . differences any fabricator can SELL in today's market.

•

Scovill Manufacturing Company, Mill Products Division, 99 Mill Street, Waterbury 20, Connecticut. Phone PLaza 4-1171.

SCOVILL MILL PRODUCTS

BRASS • BRONZE • NICKEL SILVER • ALUMINUM

Personals . . .

N. F. Vinatieri has joined Metal Control Laboratories, Inc., Huntington Park, Calif., as metallurgical engineer and will head the metallurgical department. Mr. Vinatieri is a graduate in metallurgical engineering from the South Dakota School of Mines, and for the past nine years has served as metallurgical consultant for Ducommun Metals and Supply Co., Los Angeles.

Robert D. Robertson has been appointed materials engineer at American Locomotive Co., Schenectady, N. Y. Formerly welding engineer with Air Products, Corp., Emmaus, Pa., and Fitzgibbons Boiler Co., Oswego, N. Y., Mr. Robertson has also served as senior metallurgist of American Car and Foundry Co., Berwyk, Pa., and supervisory metallurgical engineer with Black and Decker Mfg. Co., Towson, Md. He is a graduate of Rensselaer Polytechnic Institute.

Announcing

the first of a new line of controlled atmosphere heat treating furnaces

for clean hardening without decarburization

Now, for the first time, atmosphere protection in small furnaces is available with a reasonable investment and low operating costs. This new Cooley GA-3 electric furnace has been especially designed for tool rooms and small production. As a package unit it includes a fully wired temperature control panel and atmosphere generating unit. The furnace incorporates a sealed alloy retort with tightly closed door, automatic gas curtain and foot operated door mechanism.

The atmosphere is generated by cracking alcohol and water of proportions pre-determined to suit the application. Steel may be clean hardened without decarburization, or may be carburized. This patented process is simple in design and operation, and requires little adjustment.

Investigate the possibilities of this new furnace for your work. Write or wire for catalog.

COOLEY ELECTRIC MANUFACTURING CORPORATION
30 SHELBY STREET • INDIANAPOLIS 7, INDIANA

Cooley HEAT TREATING FURNACES

Fritz V. Lenel, professor of metallurgy at Rensselaer Polytechnic Institute, has been authorized by Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, to continue through 1955 his program of aluminum powder metallurgy research for the center. Dr. Lenel's investigation has been in process since 1952.

Alfred L. Gostow, plant manager of the Dodge Forge plant, Chrysler Corp., Detroit, has been promoted to manager of methods. Mr. Gostow joined Chrysler Corp. in May 1942 as general superintendent of the forging division of the Dodge Chicago plant. He was transferred to Detroit in September 1945 as assistant plant manager of the Dodge Forge plant, and in November 1950 was made plant manager.

Robert A. Willey joined the staff of the Steel Founders' Society of America on March 1st as assistant technical and research director. He was formerly chief metallurgist for the Commercial Steel Casting Co., Marion, Ohio. A member of the S.F.S.A. Technical Research Committee since 1950, Mr. Willey is also a director of the Acid Open Hearth Research Association, and has served a two-year term as a member of the Papers and Program Committee of the American Foundrymen's Society. He is a graduate of Ohio Wesleyan University and also of Ohio State University. Prior to 1942, he was for eight years a teacher of mathematics, physics and chemistry.

E. P. Best has been appointed chief metallurgist at the Ambridge, Pa., plant of A. M. Byers Co., filling the vacancy created by the retirement of veteran chief metallurgist **E. B. Story**. Mr. Best has held numerous posts in the A. M. Byers Co.'s operating department. He served for a time as assistant to the general superintendent at the company's old Girard, Ohio, plant, and in 1930 went to Ambridge as works metallurgist and was later named assistant chief metallurgist. **E. K. Foss** succeeds him as assistant chief metallurgist.

R. W. Burton, former manager of general services of the warehouse division, Jones & Laughlin Steel Corp., Pittsburgh, has been named assistant general manager of the same division.

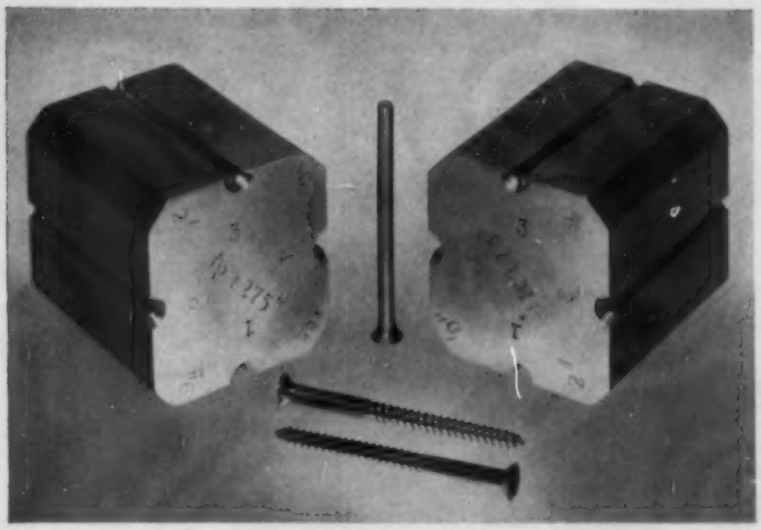
Tool Steel Topics

BETHLEHEM STEEL

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation



150,000 Screw Blanks per Dressing with This Cold-Heading Die Steel

Shown here are representative header and gripper dies used in the manufacture of wood screws by Southern Screw Company, Statesville, N. C. Made of Bethlehem Cold-Heading Quality Carbon Tool Steel, the dies are hardened to Rockwell C 59/61. They are working tools of a cold-header, and form steel, brass or aluminum stock into screw blanks, turning out up to 150,000 blanks before redressing is required.

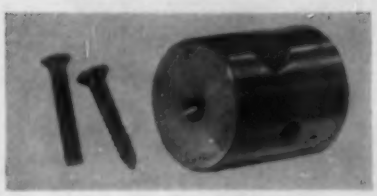
Southern Screw Company reports that they like this grade of Bethlehem Tool Steel because of its ease of machinability, uniformity of heat-treatment, minimum distortion in heat-treatment, good wear-resistance, and good shock-resistance.

Bethlehem Cold-Heading Quality Carbon Tool Steel is a superior grade of tool steel, intended for specialized types of tools where cleanliness and hardenability are important.

TYPICAL ANALYSIS

Carbon, 0.90 to 1.00
Phosphorous, 0.020 max
Sulphur, 0.020 max

Bethlehem Cold-Heading Carbon Tool Steel has high shock-resistance because it is accurately controlled for hardenability. Its controlled carbon range results in good wear-resistance, and provides the toughness to withstand cold battering.



Ask your tool steel distributor to send you a trial order of Bethlehem Cold-Heading Carbon Tool Steel. You're sure to be pleased with the way it performs.

* * * * * * * * *

DIE OF 67 CHISEL GIVES GOOD SERVICE IN MAKING PART FOR REFRIGERATOR

This blanking, drawing and forming die, made of Bethlehem 67 Chisel Tool Steel and hardened to Rockwell C 52, is used in producing refrigerator unit end caps for a manufacturer of appliances. The caps are made from steel, ⅜ in. thick, approximately 90,000 pieces being turned out before redressing is required. 67 Chisel, our general-purpose, tungsten-type of shock-resisting tool steel, is well known for its wear-resistance, and also for its low distortion in heat-treatment.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Bake Tools After Plating

Electroplating with chromium or nickel is often used to salvage tools by regaining worn dimensions, or to correct mechanical errors. It is also used for decorative purposes, and is sometimes advantageous for resisting wear or metal pickup.

Plating of hardened tools is relatively simple. Yet it can be a hazardous operation if it is not followed by tempering or baking. During deposition of the plated metal, a considerable amount of hydrogen is deposited on the tool, and some of it diffuses into the tool, causing extreme brittleness. If the tool is used immediately after plating, breakage in service may occur. To avoid this possibility, temper the tool at from 300 to 400 F for at least four hours, so as to restore its original ductility. This should be done as soon as possible after plating.

Grinding should never be attempted on the steel itself prior to tempering. If tempering is omitted, the tool will gradually recover its ductility at room temperature in from two to three weeks, but will be subject to breakage if used earlier.

Personals . . .

William M. Payne, formerly with Speer Carbon Co., St. Marys, Pa., as assistant manager, new products division, and more recently with J. W. Danforth Co., Buffalo, N. Y., as project manager, has joined his brother in a consulting engineering firm in Birmingham, Ala., offering services in electrical, chemical, mechanical and metallurgical engineering.

Myron E. Lunchick is now supervisor, structural evaluation section, David Taylor Model Basin, Washington, D. C. Dr. Lunchick was formerly senior stress analyst for Republic Aviation Corp., Farmingdale, L. I., N. Y.

David L. Wheeler has resigned from Battelle Memorial Institute, Columbus, Ohio, and is employed as a metallurgist at the Newark, Ohio, works of Kaiser Aluminum & Chemicals Corp.

Richard L. Jones, who graduated in January from the Missouri School of Mines and Metallurgy, is now employed by General Motors Corp. in their metallurgical research center in Detroit.

Max C. Farmer, formerly assistant chief of metals working division, aluminum research laboratories of Aluminum Co. of America, New Kensington, Pa., is now a staff metallurgist for the Materials Advisory Board, National Research Council, National Academy of Sciences, Washington, D. C.

William H. Graves has been elected vice-president and director of engineering of the Studebaker-Packard Corp., Detroit, for both lines of cars. Mr. Graves joined Packard in 1919 as a research chemist, advancing through key engineering assignments, and has headed engineering since 1950.

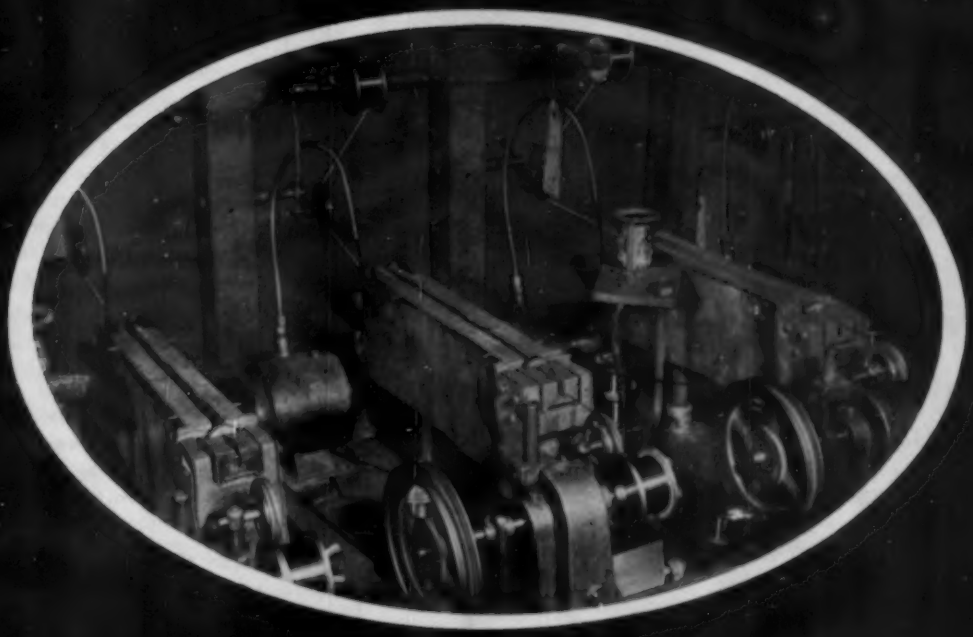
Ralph J. Kotfila, upon completing his tour of active duty as chief of the titanium section, Wright Air Development Center, United States Air Force, has joined the sales department of Rem-Cru Titanium, Inc., Midland, Pa. A native of Chicago, Major Kotfila received his bachelor of science degree from Purdue University, later attending the School of Commerce at Northwestern University. Before being recalled to active duty in 1951, he was employed as a metallurgist for General Motors Corp. at La Grange, Ill., and as plant metallurgist for Shakeproof, Inc., Elgin, Ill.

Robert F. Koenig has been placed in charge of the materials application unit of the Submarine Advanced Reactor Project at Knolls Atomic Power Laboratory, Schenectady, N. Y., which is operated for the U. S. Atomic Energy Commission by the General Electric Co. Prior to this, he was in charge of the metallurgical engineering unit for the Submarine Intermediate Reactor Project, which is now in the advanced stages of construction.

C. P. Sander, general superintendent of the Consolidated Western Steel Div., U. S. Steel Corp., Vernon, Calif., has been appointed a member of the technical council of the Board of Directors of the American Welding Society. He was elected a second vice-president of the Society in 1954.

Testing of metals made easy
...with fine accuracy assured
To test-best with mechanical ease, yet assured accuracy, for any given physical property—it is important you have *exactly the right* machine. For more than 40 years Steel City has designed and built the correct machines for various types of work, with the customers' requirements utmost in mind.
Illustrated Model UK-300-M is the *right* machine for testing Brinell Hardness where application requires limited production rate and fine accuracy. Machine is motorized, floor mounted and has wide range of application. Minimum maintenance needed.
Steel City has qualified sales representatives in major metal-working areas for your convenience. Write today for name of nearest representative . . . and detail information on complete line.
Manufacturers of machines for testing physical properties of metals, including:
Brinell Hardness
Ductility
Tensile
Compression
Transverse
Hydrostatic
Proving Instruments
Flex-Tester
. . . and Special Testing Machines.
Steel City Testing Machines Inc.
8811 Lyndon Ave. Detroit 38, Mich.

dag
DISPERSIONS



Die life extended with 'dag' dispersions

Use **'dag'** Colloidal Graphite when drawing fine wire through diamond dies: it is the only substance which will adhere to the heated wire and lubricate the dies. Not only does this *dry lubricating film* extend the life of the dies, but it produces wire of uniform diameter without the scoring and breakage frequently encountered with inferior lubricants.

Tungsten and molybdenum, notably difficult to work, are easily drawn through dies lubricated with a dilute mixture of **'Aquadag'**® and sugar solution.

To lubricate dies used in forming steel wire, a dilution of **'Prodag'**® and water is recommended. Users report more than 2200 pass-pounds per gallon of mixture with no graphite visible on the finished wire.

'dag' dispersions are also used profitably in forging, stamping, deep-drawing, piercing, casting, and stretch-forming. Write for our free booklet on **'dag'** Colloidal Graphite for Metalworking Operations, Bulletin No. 426-V1.

Dispersions of molybdenum disulfide are available in various carriers. We are also equipped to do custom dispersing of solids in a wide variety of carriers.

use 'dag' dry films for trouble-free lubrication

ACHESON COLLOIDS COMPANY
PORT HURON, MICHIGAN
...also ACHESON COLLOIDS LIMITED, LONDON, ENGLAND

Personals . . .

Kenneth A. Burnett is now employed as process metallurgist in the extrusion department, aluminum division, Bridgeport Brass Co., Adrian, Mich.

R. G. Nelson, formerly with the U.S. Bureau of Mines, Albany, Ore., is presently with the research department of Universal-Cyclops Steel Corp., Bridgeville, Pa.

Joseph Finke has resigned from the reactor development division of the U. S. Atomic Energy Commission to take a position as an associate engineer with the atomic energy division of Kaiser Engineers, Oakland, Calif.

Louis Silverman, formerly chief production engineer at the Chromatic TV Laboratory, Emeryville, Calif., is now senior engineer in the semi-conductor department of Raytheon Mfg. Co., Newton, Mass.

time marches on—

. . . yes, in hardness testing also . . .

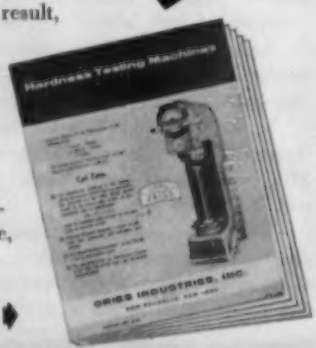
Once upon a time, somebody conceived the idea that hardness tests could be accelerated by basing the results on measurement of DEPTH of indentations, through the use of mechanical depth indicators. In fact, saving of time was the SOLE advantage which that method offered.

TODAY, THAT ADVANTAGE OF THAT METHOD HAS DISAPPEARED. It now takes less time, using the REFLEX machines, with their CARL ZEISS optical projection system, to look at the greatly magnified image of the indentations (Brinell, Vickers, etc.) and to obtain a really valuable, informative hardness test. There is no initial load, no major load, no return to the initial load. All those delays are eliminated.

Just ONE straight loading by pushbutton control and immediate indication of the test result, on one uniform scale of hardness, from very thin to heavy sections, soft or hard. And the optical system used is, of course, far more accurate and constant than mechanical depth indicators.

If interested in hardness tests of maximum accuracy and informative value, use the REFLEX system.

Write for Bulletin No. A-14 . . .



GRIES INDUSTRIES, INC.
Testing Machines Division • New Rochelle 3, N. Y.

The *Only Truly Complete Line* of Hardness Testing Equipment of Highest Quality

A. B. Kinzel, director of research, Union Carbide and Carbon Corp., New York, was awarded the James Turner Morehead Medal at the annual meeting of the International Acetylene Association. Dr. Kinzel was chosen as Morehead Medalist for his "many sound and important advances contributed to science and technology" and for his "forthright courage in presenting new ideas, his facility in explaining them to technical and nontechnical people alike, and for his gracious willingness to share with all the fruits of his sound thinking, his fertile imagination and his contagious enthusiasm". A biographical appreciation of Dr. Kinzel appeared in *Metal Progress* in August 1953.

George K. Lane has been appointed general manager of Ipsenlab, Ipsen Industries, Inc., Rockford, Ill. Mr. Lane was formerly district representative for Ipsen in Cleveland and Pittsburgh territories. In addition to his managerial duties, he will continue to serve as a sales engineer for the Rockford territory.

A. E. Tarr, formerly manager of the sales engineering division of Leeds & Northrup Co., Philadelphia, has been appointed assistant to the president. **H. Raymond Abey**, who has been manager of the eastern sales region for Leeds & Northrup, has been appointed manager of the marketing services division.

Russell B. Barnett has been elected president of Peter A. Frasse and Co., Inc., New York. Mr. Barnett has been with Frasse since 1914. He was appointed production manager at Hartford in 1917, sales manager in the same city in 1921, district manager at Buffalo in 1938, district manager in Philadelphia in 1942, and vice-president in charge of sales in 1943. Other executive changes in the company named **John D. Drummond** as vice-president in Philadelphia and **Bernard Dolan** as assistant vice-president in charge of sales in New York.

Ernest G. Thompson is employed by Rensselaer Polytechnic Institute as part-time research assistant while working toward a master's degree in metallurgy. Mr. Thompson was previously employed by Hamilton Standard Div. of United Aircraft Corp., after graduating from R.P.I. in 1952.

The illustration shows Rockwell furnaces for carburizing, crucible melting, bright annealing, casting annealing, aluminum annealing and coil wire annealing—all equipped with Spencer Turbo-Compressors.

SPENCER HARTFORD TURBOS

are recommended by

THE W. S. ROCKWELL CO.

Since 1918, now more than a quarter of a Century, Rockwell has recommended Spencer Turbos in connection with their furnaces and ovens. A few recent installations are shown above.

Spencer Turbos have met the test of time—in years and in continuous service with a minimum of shut downs and maintenance costs. The simplicity of design with wide clearances, low peripheral speeds and only two bearings to lubricate is partly responsible. Other features are described in Bulletin No. 126-A illustrated below.

THE SPENCER TURBINE COMPANY

SPENCER HARTFORD

HARTFORD 6
CONNECTICUT

494 A

Manufacturers of Turbo-Compressors and Heavy Duty Vacuum Cleaners

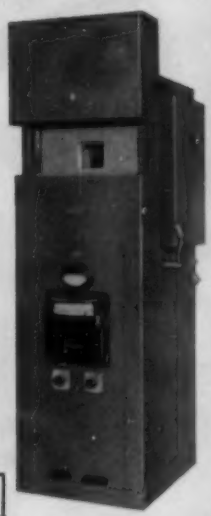
BURRELL "For Scientists Everywhere"

LABORATORY FURNACES

BURRELL *DUAL-RANGE*

Box and Muffle Type

FOR HIGH TEMPERATURES UP TO 2650° F.



Model 30 (pictured) Automatic temperature control. From 600° F. to 2000° F., use for ashing, drawing, igniting, tempering, etc. Above 2000° F., for sintering, melting, clinkering, fusing and high speed hardening. For use with 230 volt, 50-60 cycle, single phase power supply; automatic controller for 115 volt, 50-60 cycle, single phase.

CAT. NO.	ITEM	PRICE
37-442	Box Muffle Furnace, Model 30— (Heating chamber 7" wide x 8½" deep x 4" high)	1300.00

For other models—ask for Bulletin No. 315

BURRELL *UNIT-PACKAGE*

Tube Furnaces

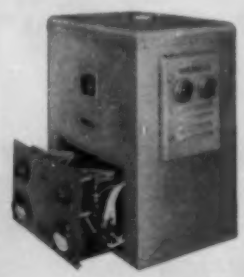
MODEL H-1-9 (pictured) For high temperature testing to 2650°F. For the determination of carbon and sulfur by combustion in ferrous metals. Available for one, two and four tubes. For use with 115 or 230 volt, 60 cycle, as specified.

CAT. NO.	ITEM	PRICE
24-934	One Tube Furnace, Model H-1-9	585.00
24-944	Two Tube Furnace, Model H-2-9	600.00
24-954	Four Tube Furnace, Model H-4-9	850.00

For other models—ask for Bulletin No. 310

EASY ACCESS PANELS FOR EASE OF SERVICING

All current models of Burrell furnaces open from the front, for ease of inspection, parts replacement and servicing when necessary.



Prices listed are F.O.B. Pittsburgh, Pa.

BURRELL CORPORATION

Manufacturers and Distributors of
SCIENTIFIC APPARATUS and LABORATORY CHEMICALS
2223 Fifth Avenue, Pittsburgh 19, Pennsylvania

Personals . . .

Alex Sherman has been appointed manager of the newly organized electronics division of the Peerless Electric Co., Warren, Ohio. Former president of the Sherman Electric Co. of Warren, Mr. Sherman will direct production of electrical and electronic devices developed by his former firm, which was recently purchased by Peerless Electric.

H. H. Hreher, formerly manager of stainless and alloy sales for Jos. T. Ryerson & Son, Inc., San Francisco Bay Area Plant, is now service metallurgist for the central sales district, Columbia Geneva Steel Div. of United States Steel Corp., San Francisco.

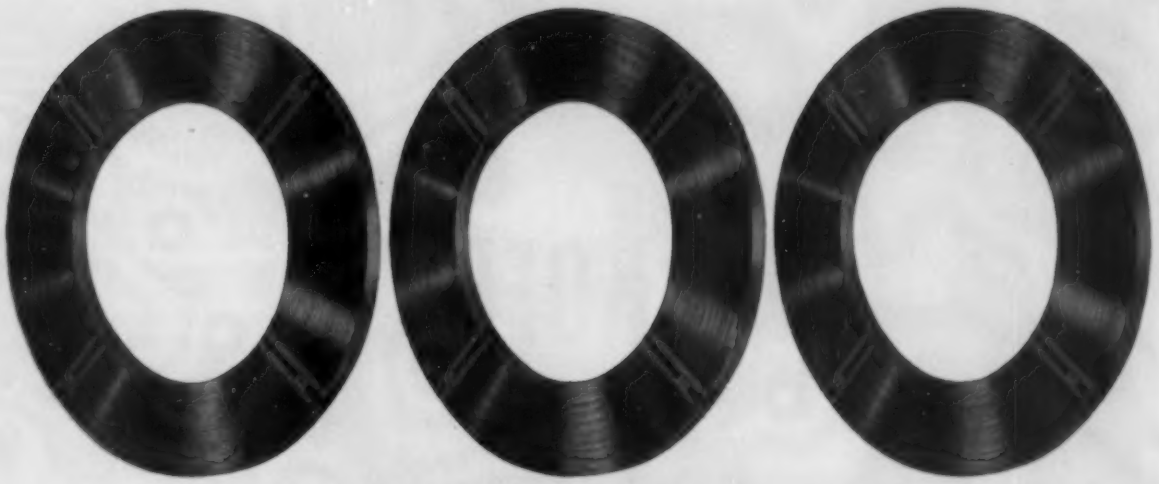
Charles E. Vest has resigned from the U. S. Atomic Energy Commission as a materials engineer, reactor materials branch, Augusta, Ga., to accept a position as aircraft research engineer in the metallurgical department of Lockheed Aircraft Corp., Marietta, Ga.

Richard Carlander, who graduated from Purdue University with a B.S. degree in metallurgical engineering last January, has accepted a position as junior metallurgist on the nuclear engine project at Pratt and Whitney Aircraft Corp., East Hartford, Conn.

Charles A. Mueller has been appointed chief engineer of Western Rock Bit Mfg. Co., Salt Lake City, Utah. His duties include the establishment of a division of the company for commercial heat treating. During the previous 15 years, Mr. Mueller served as engineer, metallurgist and assistant director of research for Lindberg Engineering Co., Chicago.

Clyde R. St. John has been transferred from the Kaiser Aluminum & Chemical Corp.'s Newark, Ohio, plant, where he held the job of production superintendent, to the company's Trentwood Works at Spokane, Wash., where he will serve as administrative superintendent.

Pieter Muije, formerly metallurgist for United States Steel Corp., Salt Lake City, Utah, is now a research metallurgist for Kaiser Aluminum & Chemical Corp., Spokane, Wash.



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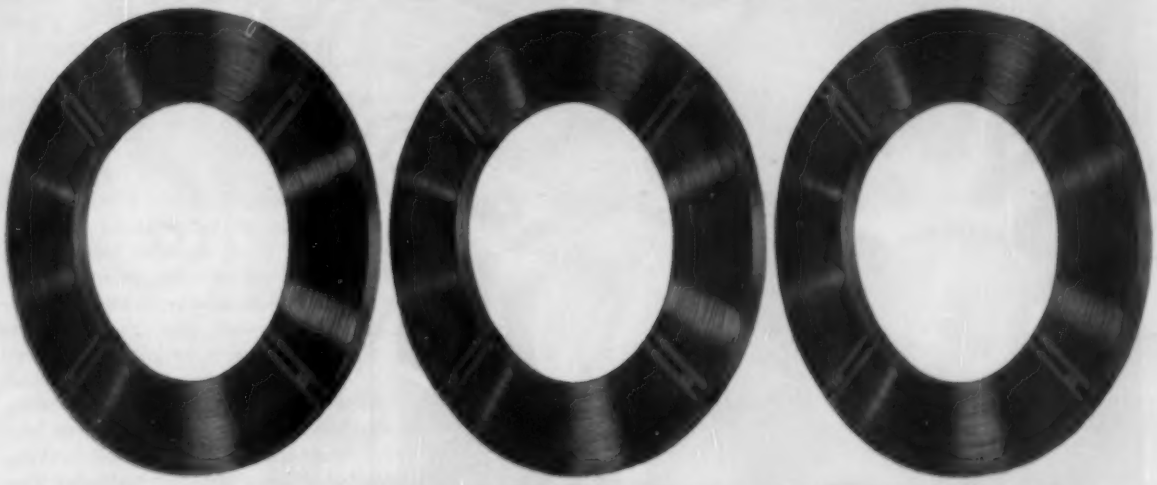

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British Preferences for Metals in Refinery Equipment*

Factors leading to undue wear and tear on metals used in the construction of oil refinery plants and process equipment in Great Britain are given careful evaluation by metallurgists associated with these plants to insure safe and uninterrupted operations, many of which are interconnected and therefore interdependent.

Greatest tonnage of metal is mild steel of the structural type. In its selection particular emphasis is placed on weldability and the avoidance of brittle fractures in welded structures. Introduction of a steel specification clause guaranteeing a Charpy (Izod V-notch) impact value of 20 ft-lb. at a suitably low temperature, such as 32° F., has many advocates.

In considering the suitability of commercial grades of carbon steel for use at temperatures down to −40° F. a series of temperature-impact curves was developed for the material in various conditions. These demonstrated that the transition temperature is appreciably affected by the treatment given the steel. Hence, in application of the materials, precautions were taken that they were first normalized; welding was done with low-hydrogen electrodes, and a final stress relief was given after all bending and welding operations.

Corrosion is a major metallurgical problem in refinery metals, both ferrous and nonferrous. It encompasses a wide variety of forms — electrochemical, dezincification, hydrogen blistering, stress-corrosion and corrosion fatigue.

Principal factors determining the corrosivity of crude oil are its sulphur content and amount of entrained salt water. The salts, predominantly magnesium and calcium chlorides, are converted in the crude oil heaters to hydrogen chloride. In cooler regions of the heater tubes and in connecting lines and condensers

(Continued on p. 136)

*Digest of "Metals in Oil Refining," by I. H. Thomas, *Journal* of the Birmingham Metallurgical Society, Vol. 34, June 1954, p. 51-70.

6" Model RB 6-Spindle Acme Gridley Automatic Screw Machine

ONLY 5 MORE LIKE IT IN THE WORLD!

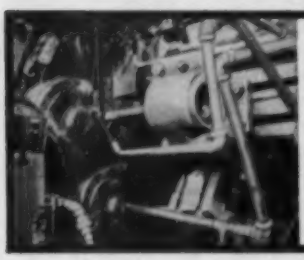
Owned by Jessen Manufacturing Company, today's most advanced automatic screw machine uses Cities Service Cutting and Hydraulic Oil

Weighing 39 tons and powered by a 60 H.P. motor, this 6-inch, 6-spindle Acme Gridley Automatic Screw Machine is one of the only six now in existence . . . and the only one owned by a job shop. Featuring a combination pneumatic-hydraulic operation, it can turn out a single load of stock weighing 3 tons!

The owner is Jessen Manufacturing Company of Elkhart, Indiana—since 1923 famous for keeping on top of new developments. It's not strange, therefore, that for this advanced new machine they chose a top quality coolant—a Cities Service cutting fluid.

Says President J. H. Jessen: "We're happy to say that the Cities Service cutting oil we use today is one of the finest all-around cutting oils we have ever used. In years past, we felt that if a cutting oil was good, it had to be black, heavy, and odorous. Cities Service has changed our minds with a cutting oil that has outstanding cooling abilities, good chip drain-off, is anti-weld . . . and yet possesses light, clear color and has no noticeable odor. In addition, Cities Service Pacemaker Oil used in hydraulic systems, and Amplex Lubricating Oil are doing an outstanding job throughout our shop. We proudly recommend *all* these Cities Service Oils."

For more information on the complete line of Cities Service cutting fluids, call in a Cities Service Lubrication Engineer. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.



Light, Clear Coolant in Acme-Gridley Automatic is Cities Service cutting oil. "Outstanding cooling, anti-weld, and chip drain-off ability," says Jessen. Firm also praises Pacemaker Oils, used in their hydraulic operations.

Jessen Mfg. Company, Inc. Mr. Jacob Jessen, Pres., in business since 1923, has earned reputation of keeping on top of new developments. In 1935, he was one of the first to install 6-spindle, anti-friction bearing screw machine.

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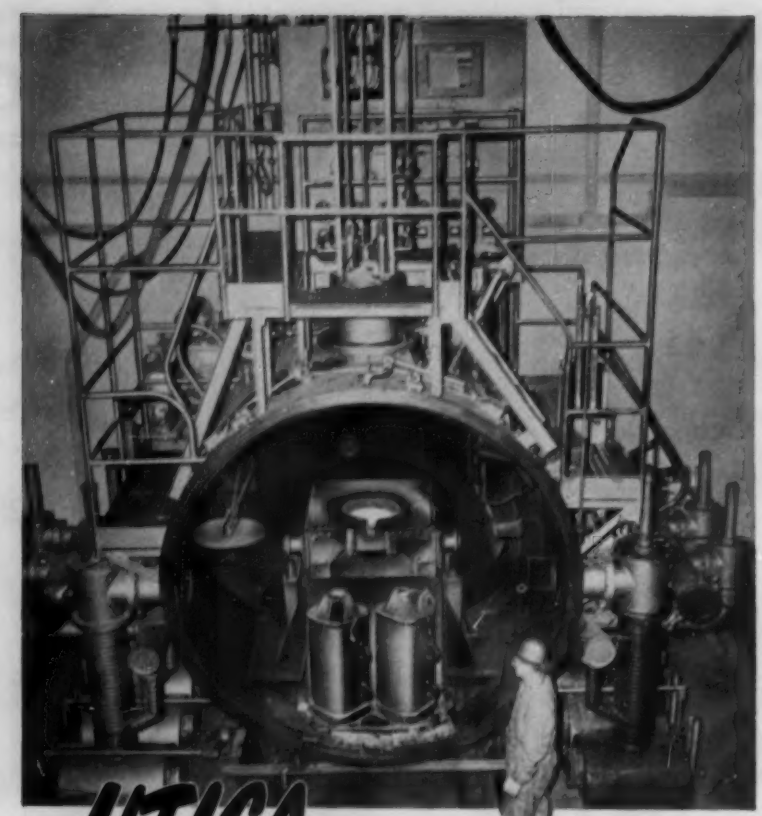

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Offer of our facilities is subject to priority of national defense orders.

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Experience gained in literally hundreds of melts has led to regular and consistent volume production with the most rigid control of the properties of the alloys.

In addition, UTICA, alone, offers not only static but *centrifugal* castings as well. The latter often permit significant reduction in costs.

The Metals Division at UTICA invites inquiries from prospective customers. Through refinements in technique, costs are constantly being reduced—and the Division is glad to work closely in resolving the customer's metallurgical problems.

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Refinery Metals . . .

where water is present, the resulting hydrochloric acid leads to serious corrosion of the electrochemical type. It can be controlled to a large degree by neutralization, carried out in two stages. In the first, a solution of caustic soda is introduced into the crude ahead of the heater, and in the second an ammonia solution is fed into the stream as it leaves the top of the heater column. Close control is maintained by means of pH recorders, with a pH range of 6 to 8 being held.

Sulphur in crude oil is converted to H_2S, which attacks steel fairly rapidly at high temperatures. In addition, H_2S aggravates the aqueous corrosion by HCl in cooler sections. High-temperature attack can be overcome by the use of alloy steels, such as 2.25% Cr, 1% Mo and 4 to 6% Cr, 0.5% Mo.

Many corrosion problems are most closely associated with chemical plants operated by refineries for the manufacture of industrial solvents and other organic chemicals from petroleum. Most of the chemical reactions in this area derive from the use of sulphuric acid at a concentration of 65 to 85% and over a considerable range of temperature.

To a considerable degree mild steel and lead are specified as complementary materials in acid service, the former being suitable for cold acid of high concentration, while lead and lead membrane plus brick lining take over at lower concentrations and higher temperatures. Where, for reasons of extremely high temperature or for mechanical demands, they are unsuitable, special materials are employed, including glass linings, synthetic rubbers, plastics, silicon iron, nickel-base alloys, copper and its alloys, stainless steel and tantalum.

Dezincification is a refinery problem principally associated with condenser service. Since most plants use sea water for cooling, it is the general practice to specify brass for condenser tubes and sheets. Two varieties are favored – aluminum brass of 76% Cu, 22% Zn, 2% Al composition, or Admiralty brass of 70% Cu, 29% Zn, 1% Sn analysis. Both are inhibited against dezincification by addition of 0.02 to 0.06% As.

(Continued on p. 138)

FOUR *REALLY TOUGH* MUELLER BRASS CO. REFRACTORY BRONZE ALLOYS IN ROD FORM

"TUF-STUF" ALUMINUM BRONZE
"600" SERIES BEARING BRONZE
MANGANESE BRONZE
ALUMINUM SILICON BRONZE

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NAME OF ALLOY	ALLOY NO.	YIELD STRENGTH AT 0.5% EXTENSION LBS./SQ. IN.	TENSILE STRENGTH LBS./SQ. IN.	ELONGATION % IN 2 IN.	BRINELL HARDNESS	RELATIVE MACHINABILITY —FREE CUTTING BRASS = 100%	ALLOY CHARACTERISTICS
TUF-STUF ALUMINUM BRONZE	224-E	60,000	90,000	15	175	30	Resists oxidation and retains strength at elevated temperatures. Lightweight. Used in aviation industry.
TUF-STUF ALUMINUM BRONZE	224-C	62,000	95,000	9	185	35	Properties generally higher than 224-E. Non-Galling. Acid and corrosion resistant.
MANGANESE BRONZE—A	241-A	55,000	78,000	20	150	25	High torque resistance. Tough. For screw machine parts and forgings — valve stems, bolts, airplane parts.
MANGANESE BRONZE (HIGH TENSILE—GRADE B)	721	68,000	115,000	10	200	35	Highest strength of the copper base alloys. Good shock and wear resistant properties. Used for rollers, rotors, valve stems.
FORGEABLE BEARING BRONZE	600	40,000	78,000	15	165	25	For use where excessive pounding action encountered. Excellent bearing properties. For bushings, gears, marine hardware, etc.
FORGEABLE BEARING BRONZE	602	40,000	74,000	12	150	65	Used with hard or soft mating members that do not have a high polish. Modification of 600 alloy—for use where difficult machining is necessary.
ALUMINUM SILICON BRONZE	802	45,000	90,000	15	175	65	Excellent machinability for high strength bronze. Corrosion resistant. For pole line hardware. Non-magnetic.

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FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT

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ALLOY WELDS X-ray inspected . . . free from slag, air pockets, cracks. No premature failures due to these causes.

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If you require neutral salt pots of this type (any size), you will want specifications and quotations that will clearly show cost-cutting. Write for complete details of this up-to-the-minute equipment . . . or any other type of fabricated heat and corrosion resistant alloys.

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Easier Operation, Lower Cost

Refinery Metals . . .

Hydrogen blistering of steel at temperatures low enough for a free water phase to be present is a corrosion effect frequently encountered. Its cause is the presence of contaminants in the aqueous phase, such as hydrogen sulphide, acids, cyanides and ammonia. The hydrogen of the corrosion reaction penetrates into the steel, building up internal pressure leading to blistering, fissuring and embrittlement. Blisters may vary from microscopic to large swellings several feet in diameter.

Mechanism of the attack hinges on the fact that atomic hydrogen of the corrosive action diffuses readily through the steel and, at focal points such as discontinuities, it forms molecular hydrogen which cannot diffuse outward. Blisters have been known to form on the wall of a vessel, for example, in which the pressure is little more than atmospheric, but the internal pressure in the blister is sufficient to tear the steel apart.

Corrective methods are still under study. One which has been helpful thus far is to wash the active stream with large volumes of water to dilute and remove impurities responsible for the initial corrosion.

Season cracking of condenser tubes is a form of stress-corrosion resulting from the combination of residual stresses from cold drawing the brass and the presence of ammonia and nitrogen-bearing contaminants in the water. It usually can be avoided by a final anneal of the brass tube in its manufacture. Another form of stress-corrosion, caustic cracking of welded steel equipment handling caustic soda, can be minimized by a stress relief after welding.

One item of refinery equipment most susceptible to creep failures is the heater tube. Carbon steels usually are specified for temperatures up to 842° F., while at higher temperatures the 2¼ Cr-Mo and 4 to 6% Cr-Mo types are brought into service. Where demands are severe, chromium-nickel steels of the 18-8 and 25-20 analysis are favored. Internal coke deposits on the tubes are undesirable and can be particularly troublesome in high-temperature heaters because steels which may be operating at conditions already ap-

(Continued on p. 140)

For Your Plating File!

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The use of a Baker & Adamson Tin Fluoborate bath in electro-tinning copper wire results in a uniform, easily-controlled tin coating. Tin consumption is reduced more than two-thirds as compared with hot-dipped coatings.

Moreover, copper wire with a fluoborate-plated tin coating of 100 millionths of an inch may be readily drawn through dies for burnishing or for reduction in gage. For example, a plated No. 20 wire can be reduced to a No. 34 wire—a type of processing impractical with hot-dipped wire because of the structure of the coating and its non-uniformity.

The electroplated wire comes from the fluoborate bath with a fine grain coating that has a white matte color, excellent solderability, and good shelf life. The fluoborate bath has no fumes, requires no ventilation, and operation is fast and simple compared with alkaline baths. For full information, write for Baker & Adamson Technical Bulletin TC-43441, or call your nearest B&A office. *No royalties need be paid to use this process!*

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Refinery Metals . . .

proaching the stress-rupture limit may exceed the limiting temperature as the result of the insulating properties of the coke. This leads to gradual bulging of the tube, and eventually to rupture. Steels of the austenitic type are selected with due regard to intergranular carbide precipitation and sigma phase formation.

A. H. ALLEN

Symposium on Stress-Corrosion

Part II

*By W. D. Robertson**

THE FINAL session began with "Occlusion of Hydrogen in Iron and Its Alloys", by W. R. Heller of the Shell Development Co., in which the general problem of hydrogen in metals and its relation to embrittlement phenomena was considered. The published experimental work dealing with the occlusion and diffusion of hydrogen in iron, nickel, and its alloys was reviewed. It was emphasized that above 400° C. (750° F.), the solution and diffusion of hydrogen seem to obey simple laws; below this temperature deviations appear that are associated with delays in reaching equilibrium, with increased and sometimes exothermic occlusion, and with decreased diffusion. The separate theories which have long been known to describe volumes and surface sorption of hydrogen were outlined and combined to show that occluded hydrogen preferentially finds its way to internal surfaces that operate as fracture nuclei.

Continuing on the problem of hydrogen embrittlement, W. M. Baldwin, Case Institute of Technology, presented a summary ("Hydrogen Embrittlement") of his recent work on the effect of temperature and strain rate on the ductility of steel containing hydrogen,

(Continued on p. 142)

*A report of "Symposium on Stress-Corrosion Phenomena" held during the 106th Meeting of the Electrochemical Society, Oct. 3-7, 1954 at Boston, Mass. The first part of this report was published in the April issue, p. 140. Professor Robertson is in the department of metallurgy at Yale University.

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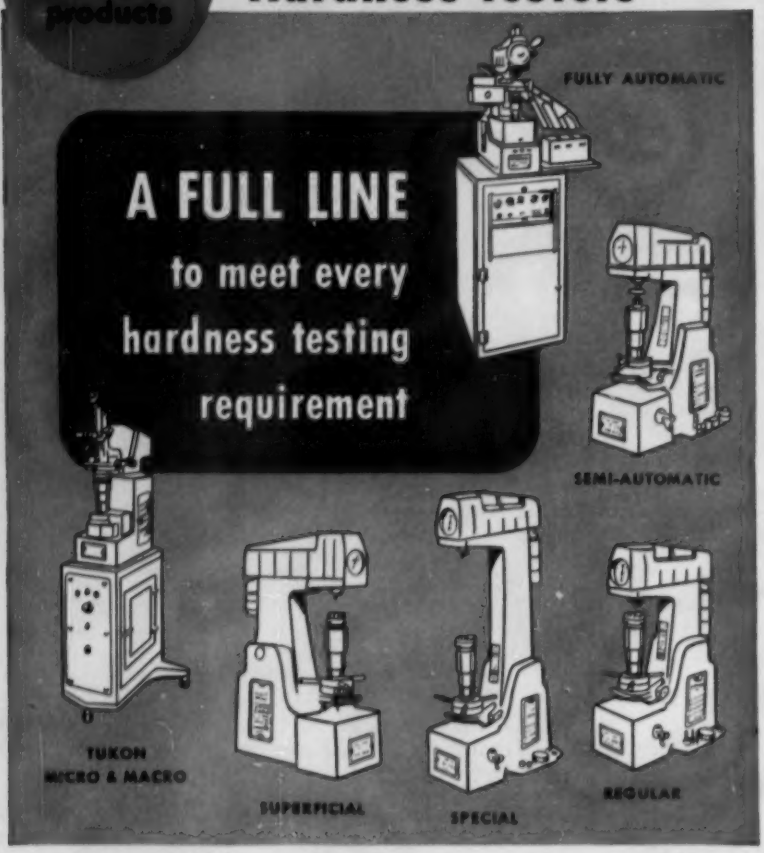

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Stress-Corrosion . . .

charged from sulphuric acid. The numerous variables associated with embrittlement were systematically separated into their time and temperature-dependent components. Professor Baldwin also presented the results of very recent work on the effect of surface layers charged with hydrogen and demonstrated how the entire specimen appears to be embrittled when the surface alone is saturated with hydrogen; embrittlement disappears when the charged surface is machined away. It appears that a very thin layer, about 10^{-3} in., is sufficient to cause brittle fracture in a large tensile specimen. The significance of surface cracks appears as an important part of fracture in otherwise ductile metals.

Prof. R. N. Parkins of the University of Durham, England, in his paper "Caustic and Nitrate Cracking of Steel", emphasized the distinction between intercrystalline and transcrystalline cracking. He pointed out that conditions at the grain boundaries are inherently dependent on the type of system, the presence of precipitates and impurities. Transgranular cracks, on the other hand, are not so obviously dependent on heat treatment and composition. The reasons for the anodic character of the grain boundary and the specific character of the medium causing intergranular cracking in nitrate solutions were presented in terms of metallurgical variables of boundary structure, composition and heat treatment, carbide distribution and cold work. It was concluded that an intercrystalline crack can continue to advance by the simultaneous action of corrosion and mechanical tearing over distances of a few atom spacings so that islands of misfit in the boundaries, considered as microcracks, become joined as a single macrocrack.

U. R. Evans of Cambridge University, England, contributed a paper on the mechanism of chemical cracking in which he emphasized the high speed of crack propagation that makes it difficult to visualize the mechanism as one of removal of material by electrochemical action; current densities would have to be improbably high. Dr. Evans also observed that hydrogen may play a

(Continued on p. 144)

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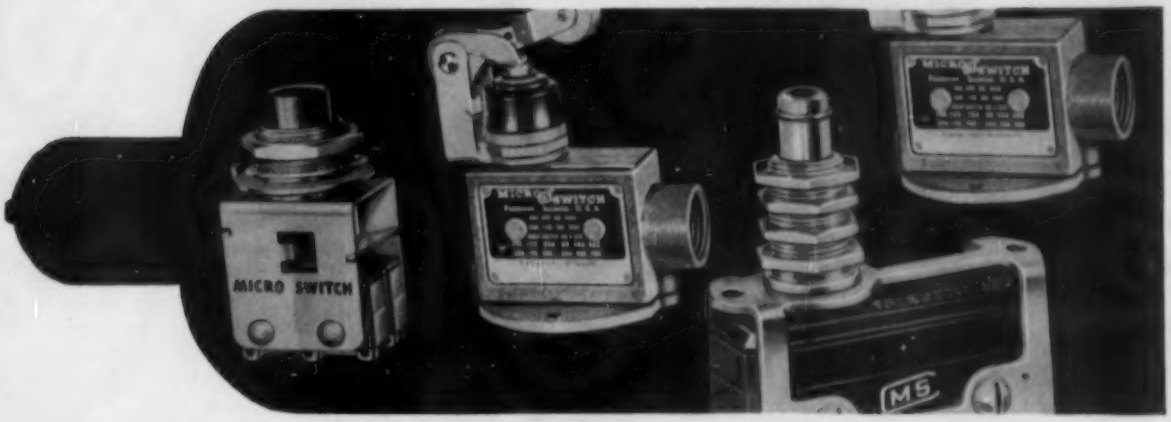

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Lloyd Froning, Tool Room Supervisor
Micro Switch Division of
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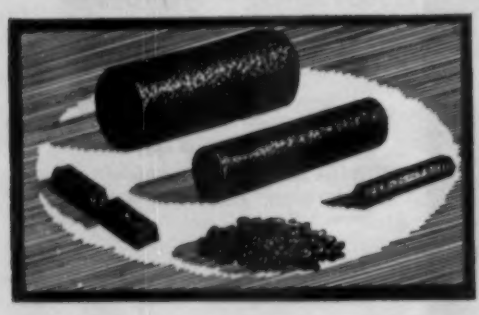

MasterMet alloys are available in ingot, shot, billet or short (6" dia.) cast bar forms and are normally shipped in drums. Specifications, weight, lot and customer's order number are clearly imprinted on container, making selection and storage a simple matter.

*Cannon-Muskegon furnishes notarized certificates of analysis to meet prescribed metal specifications. For more information about this, and complete technical service, write for New MasterMet Bulletin.

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Stress-Corrosion . . .

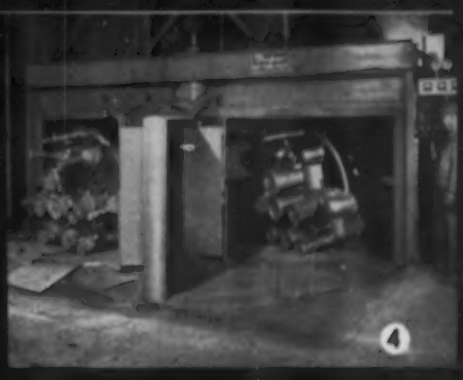
significant role in corrosion cracking, particularly if hydrogen diffuses in and subsequently fills possible microcracks in grain boundaries, thus contributing to the total stress initiating fracture.

A report on "Laboratory Investigation Techniques Relating to Stress-Corrosion Cracking", by H. R. Copson of the International Nickel Co., was a critical review of the problem of laboratory evaluation of stress-cracking phenomena. Dr. Copson classified the various types of failure occurring in service and described the problem of evaluating accelerated laboratory tests, including their correlation with service experience, and the possibility of predicting the behavior of new alloys or the susceptibility of old alloys in new environments.

Summary – The explanation of stress-cracking phenomena that emerged from this group of papers and subsequent discussion was certainly one of considerable complexity; however, it was also apparent that progress has been made in the past ten years toward a separation of the various factors. Intensive study of these individual components of the problem in terms of chemistry, structure and mechanics is in progress and, while no single mechanism is likely to be adequate for all aspects of the problem, it seems apparent that a limited number of basic principles are emerging on which at least approximate predictions of susceptibility may be based.

Of the many ideas and new experiments that were presented in this symposium, perhaps the two most significant developments were (*a*) that we now have a more comprehensive understanding of the structure-sensitive character of corrosion in homogeneous alloys, and (*b*) that everyone strongly emphasized the significance of mechanical cracking, triggered at a corrosion site or a fracture nucleus associated with hydrogen.

In view of the interest in this subject, it is anticipated that the papers and discussion, together with a few papers already published that are necessary for a comprehensive treatment, will be assembled into a monograph and published at the earliest possible date.



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High Temperatures Reveal Structure of Grains*

ALTHOUGH investigations using X-rays have shown that the individual grains of a metal are composed of small crystalline blocks, up to now microstructural studies have not revealed their size and form. To obtain micrographic evidence of this block structure, the authors used the method of heating in vacuum at high temperatures rather than the usual room-temperature metallographic techniques.

The specimens used were 60 x 10 x 3 mm. (2.4 x 0.4 x 0.08 in.) and were heated by a 50-cycle alternating current. One face of the specimen was given a metallographic polish, and the heating was done in a vacuum of 10^{-4} to 10^{-5} mm. of mercury to prevent oxidation. Up to 1400° C. (2550° F.) the temperature was measured with a thermocouple, but temperatures up to 2000° C. (3600° F.) and higher were estimated from the electrical resistivity of the specimen.

In addition to the well-known effect of vacuum heating in revealing grain boundaries, it was observed that when pure metals were heated to 75 or 80% of their melting temperatures a pattern of striations appeared within the grains, suggesting that grains are composed of flat blocks about 100 to 1000 lattice distances in thickness. In a specimen of pure molybdenum the striated structure appeared after a 20-min. treatment at 1450° C. (2640° F.), and in pure tungsten it appeared after a 15-min. treatment at 2000° C. (3600° F.). It is notable that the striations bent at the grain boundary as though the boundary had a different strength than the grain proper.

Since the molybdenum and tungsten were of high purity, it was decided to investigate the behavior of a solid-solution alloy, and a 0.45% carbon steel was chosen for this purpose. Heating for 11 hr. at 1100° C. (2000° F.) again revealed a block

(Continued on p. 148)

*Digest of "Structure of Metal Grains at High Temperature", by I. A. Oding and M. G. Loxinskii, *Doklady Academii Nauk SSSR*, Vol. 86, 1952, p. 707-709.

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Brazed joints on aircraft engine intake lines

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EQUIPMENT:
250 k. v. X-ray Machine

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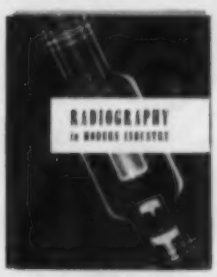

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Grain Structure . . .

structure, although somewhat different in appearance than that of molybdenum and tungsten. This difference was attributed to the different crystal structure of austenite and to its chemical inhomogeneity.

A. G. Guy

Staining of Alclad Sheets Treated in Salt Baths*

Appearance of gray stains on cold rolled sheets of clad aluminum alloy is a phenomenon associated with their heat treatment in molten sodium nitrate at about 900° F., a heat treating bath favored in Great Britain because of the short time cycle involved. Such staining occurs only occasionally, usually when a salt bath becomes slightly alkaline; however, the stain is often the cause for rejecting treated material.

Specifically, stains have been observed when the free alkali content of the salt exceeds 0.03% by weight, expressed as Na_2O. Combined alkali in the form of carbonate is not a factor in staining. Examples of analyses of two baths, one producing stains and the other not, are:

	Percent Salt	
Constituent	Stain	No Stain
Sodium nitrite	9.6	9.5
Combined alkali*	0.22	0.28
Free alkali*	0.06	0.009
Sulphate	Nil	Nil
Chloride	0.04	0.06
Iron	0.0009	0.0072
Silica	Nil	Nil
Aluminum	0.002	0.002
Sodium nitrate	Bal.	Bal.

*As Na_2O

Two kinds of staining have been noted. One is identified as "instantaneous" and occurs almost immediately with immersion on those areas of a sheet where the salt is momentarily chilled and solidified on the surface. The other is called "immer-

(Continued on p. 150)

*Digest of "Staining of Clad Aluminum Alloy Sheets During Salt Bath Heat Treatment", by E. C. Williams and H. J. G. Challis, *Journal* of the Institute of Metals, Vol. 82, June 1954, p. 465-469.

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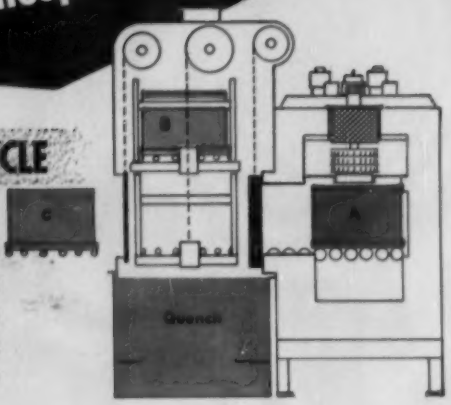
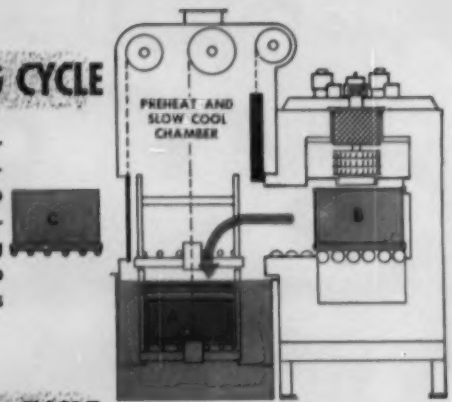
Step 1–LOADING CYCLE

Box A containing full furnace load of parts processing in work chamber. Box B—fully loaded, pre-heats in the upper vestibule. Box C—fully-loaded, waits on conveyor.



Step 2–QUENCHING CYCLE

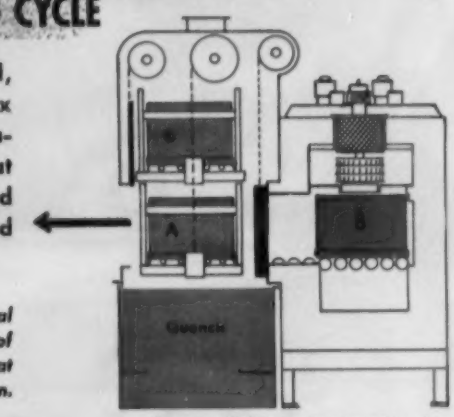
Box A completely processed, moves out to elevator and is lowered into quench; bringing preheated Box B to loading level. Box B is pushed into heat chamber and door is closed.



Step 3–RELOADING CYCLE

After proper interval, outer door is opened. Box C is placed on upper elevator and raised to pre-heat position as Box A is lifted from quench and removed from lower elevator.

Sealed Cycles' double door seal affords complete flexibility of processing without exposing heat chamber to air contamination.



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Staining of Alclad . . .

sion" staining and results in stains which are whiter in appearance than the instantaneous variety and which arise only when free-alkali content of the bath exceeds 0.10% Na_2O. The first type of staining may develop at free-alkali contents between 0.03 and 0.10% Na_2O.

Electron diffraction examinations have established that instantaneous stains initially are amorphous alumina, later converted to various crystalline modifications with further heating. Immersion stains have proved to be sodium aluminate ($NaAlO_2$).

Conditions which tend to accelerate decomposition of salt, leading to increase in free alkali, must be avoided. One is the addition of sodium nitrite to baths, frequently done to prolong the life of iron containers. Where electric immersion heaters are used, it is seldom necessary to make nitrite additions.

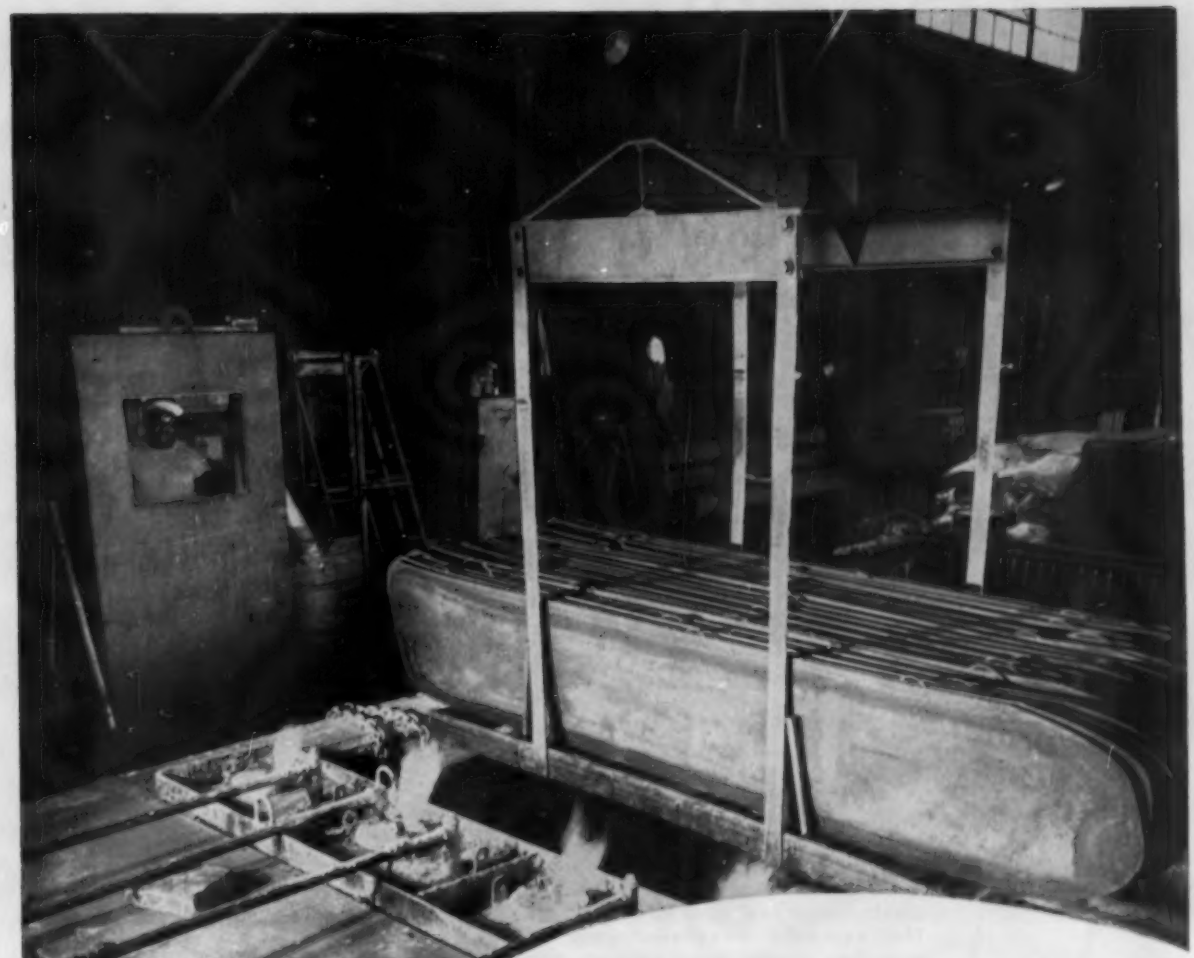
Accidental contamination of baths with foreign matter, such as oil or grease, is likely to accelerate salt decomposition and precautions should be taken to prevent it. Furthermore, periods of heat treatment above 900° F. should be as short as practical.

Baths that do produce stains may be reconditioned by treatment with gaseous carbon dioxide and thus bring the free-alkali content below 0.03%. An instance is cited of a 30-ton production bath in a staining condition which was treated by passing dry CO_2 through an iron pipe with the outlet immersed in the salt. Before the treatment the free alkali content was 0.055% and the carbonate content 0.20% (both expressed as Na_2O).

During a 7½-hr. treatment, about 17 lb. of CO_2 was used. After treatment the result was a marked decrease in extent and severity of staining and the free alkali decreased to 0.04%. Gassing of the bath, done wherever possible between heat treatments, practically eliminated staining and progressively lowered the free alkali.

Elimination of the last traces of staining, involving neutralization of the remaining free alkali to below 0.03%, required treatment over a much longer time than that needed to effect the first marked improve-

(Continued on p. 152)



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Staining of Alclad . . .

ment. However, eventually the salt was reconditioned to yield completely stain-free sheets.

Free-alkali content also decreases when fresh salt is added to compensate for dragout and a steady volume of processing, necessitating frequent topping-up to the working level, helps to keep alkalinity low. Conversion of free alkali to carbonate by slow absorption of atmospheric CO_2 does occur, but cannot be relied upon to counteract any abnormal increase in alkalinity.

A. H. ALLEN

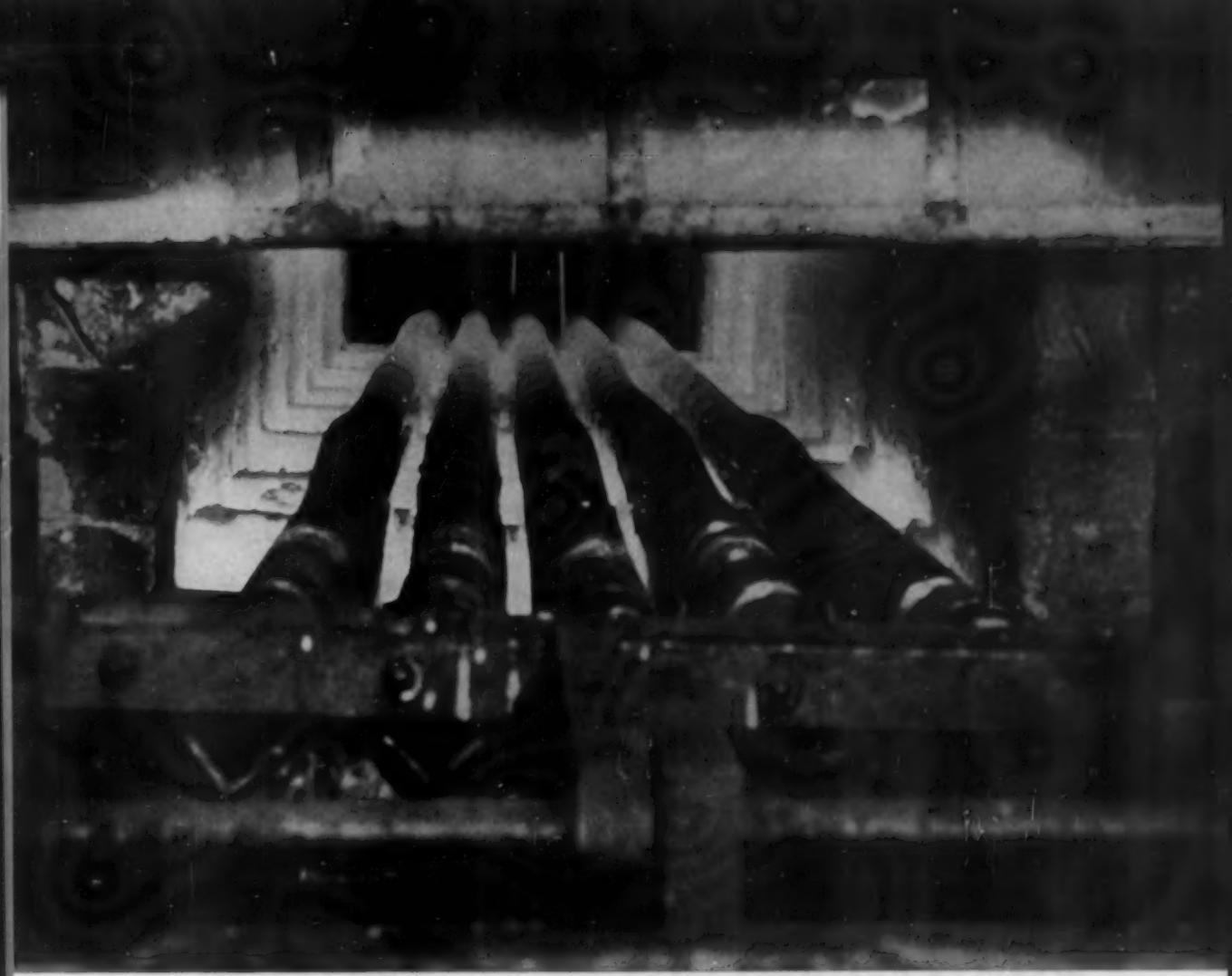
Effect of Beryllium Alloying Additions*

IMPROVED production facilities as well as new sources of beryl have combined to make available a relatively plentiful supply of beryllium. While pure beryllium metal has been employed in X-ray windows and has a wide potential use for nuclear reactors, at present it is primarily used in magnesium, aluminum, nickel and copper-base alloys in which small beryllium additions effect large property changes, so that the use of a relatively expensive metal may represent economy. The most extensive use of beryllium is in copper alloys because of its ability to harden copper by low-temperature aging from a relatively soft annealed state to strengths far above those of other copper-base alloys, retaining the good thermal conductivity and corrosion resistance of the base metal. Beryllium copper is available extensively in both wrought and cast forms.

Wrought forms of beryllium copper are available as strip, rod, bar and wire in annealed, cold worked (one-fourth to full hard), and heat treated conditions. In the solution treated condition, the alloy is soft and can be readily worked. Strip can be blanked, formed, deep drawn or spun, while rod can be forged, swaged and machined. However, after heat treatment, strength and

(Continued on p. 154)

*Digest of "Beryllium as an Alloying Addition," by L. David, *Metallurgia*, Vol. 50, November 1954, p. 236-238.



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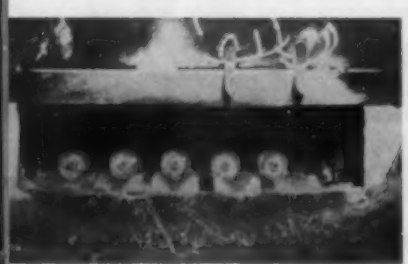

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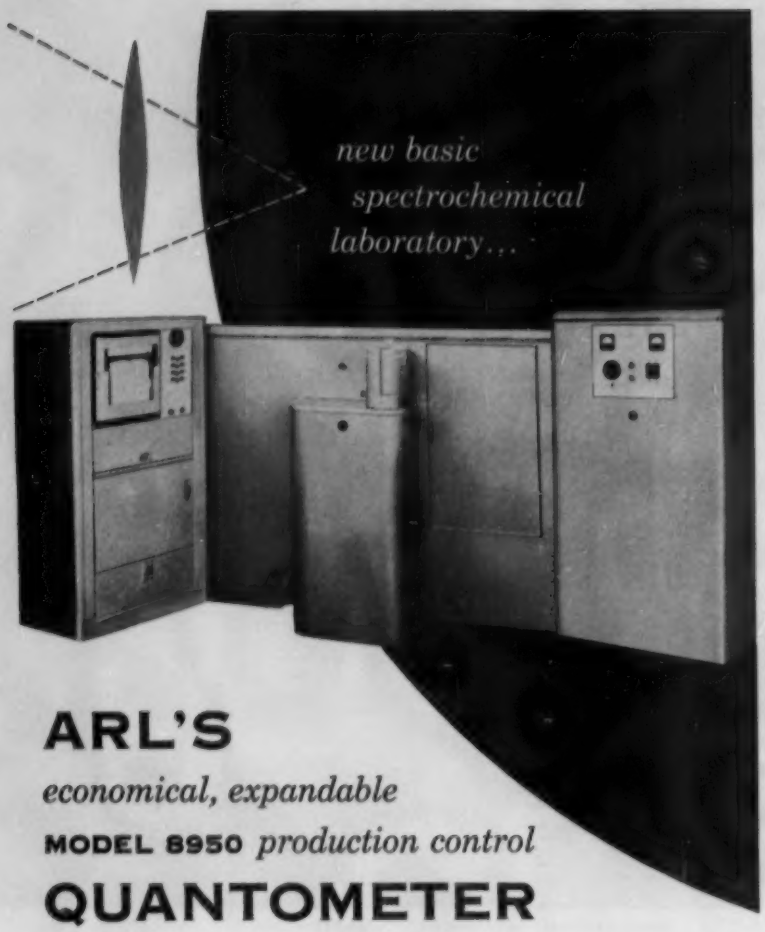

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Beryllium . . .

hardness are greatly enhanced and high fatigue strength is developed. Wrought alloys are used in current-carrying springs and contacts, electronic devices, instruments and controls, as well as in automotive, aviation and machinery parts.

Beryllium is introduced to copper as a beryllium-copper master alloy containing around 3.5 to 4.25% Be. The high-strength alloy contains from 1.8 to 2.05% Be and 0.18 to 0.30% Co; it is also available in less expensive form but with lower strength (1.6 to 1.8% Be). When fully heat treated it combines good electrical conductivity (15 to 25%) with the highest strength (up to 200,000 psi. at room temperature) and hardness (up to Rockwell C-45) of any copper alloy. Because of excellent resistance to fatigue, corrosion and wear, this nonmagnetic alloy is ideal for springs, diaphragms, bellows, aircraft engine parts, electronic equipment, flash welder dies, and bearing materials.

The usual high-conductivity alloy has lower strength (up to 115,000 psi. tensile) but better electrical conductivity (25 to 60%). It contains about 0.4 to 0.7% Be and 2.35 to 2.7% Co. Another high-conductivity alloy has 0.25 to 0.5% Be, 1.4 to 1.7% Co, and 0.9 to 1.0% Ag. This alloy was developed for resistance welding dies and electrodes having especially low surface contact resistance.

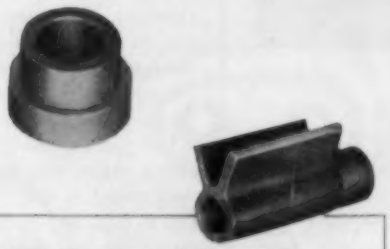
A range of heat treatable beryllium-copper alloys is available to the founding trade in convenient sizes for remelting and casting. These alloys can be handled by sand, investment, pressure, plaster mold and permanent mold techniques and are characterized by excellent fluidity and amount of detail which can be obtained in the casting.

The most widely used beryllium-copper casting alloy contains 1.9 to 2.15% Be, 0.35 to 0.65% Co and 0.20 to 0.35% Si. The alloy is especially suited to precision investment castings because of its excellent fluidity and low pouring temperature. The most common use is for nonsparking tools. Other applications employing sand and other casting techniques include bushings, cams, scraper blades and electronic parts.

An alloy with a beryllium content

(Continued on p. 156)

ACCUMET PRECISION INVESTMENT CASTINGS



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AISI 4620 — Carburizing
Mod. 4140 — Medium to High Tensile
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HYCC Air-Hardening Tool Steel
Rezistal 410 — Hardenable Stainless
Rezistal 303 — Free Machining Stainless
Rezistal VT — AMS 5385B High Temperature
Rexalloy — Cr-W-Co Alloy
Alnico Magnets

Whatever the grade of steel or high-alloys your specifications call for, you can get it in Crucible ACCUMET® precision castings.

And you can depend on the quality of ACCUMET castings, for they are made by the Country's leading specialty steel producer . . . to long established steelmaker's melting standards, in modern electric furnaces. The composition of ACCUMET is carefully controlled by chemical analysis of the *casting* — not merely of the remelt stock charged into the furnace. This extra control of analysis means better uniformity in response to heat treatment, hardenability and performance.

Put an end to costly machining of parts. Let your Crucible representative show you how ACCUMET precision investment castings can save you time and money.

54 years of Fine steelmaking

CRUCIBLE first name in special purpose steels

ACCUMET PRECISION CASTINGS

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

REX HIGH SPEED • TOOL • REZISTAL STAINLESS • ALLOY • MAX-EL • SPECIAL PURPOSE STEELS

Use
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Spring Designers: You can readily select a material with just the right combination of properties for your tough spring applications from the alloys we fabricate into wire, rod and strip. Alloys such as Monel, K Monel, Inconel, Inconel X, Nickel, Duranickel, Austenitic, Ferritic and Martensitic Stainless Steels and special alloys are available in a wide range of tempers and special treatments. These materials feature high strength and fatigue properties at elevated temperatures, good ductility at sub-zero temperatures, low magnetic permeability and excellent resistance to a wide variety of corrosive conditions.

Alloy Metal Wire Division engineers will work closely with you to develop any special engineering and fabricating properties you may require. Your inquiries are always welcome.

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ALLOY METAL WIRE DIVISION

H. K. PORTER COMPANY, INC.
Prospect Park, Pennsylvania

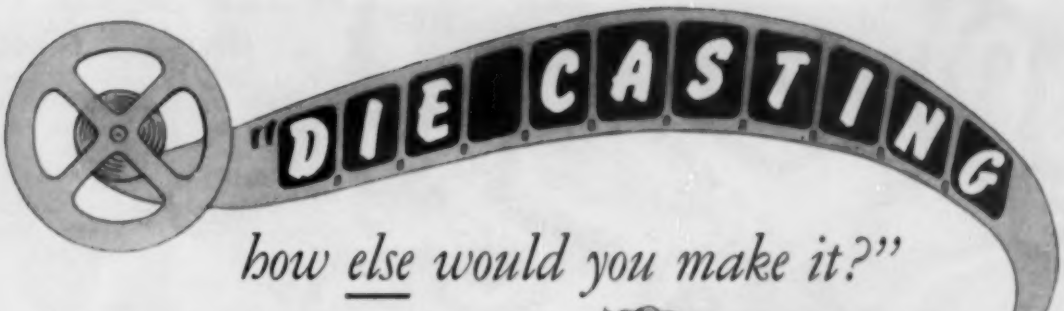
Beryllium . . .

of 2.5 to 2.75% is used for pressure-cast molds for plastics and other applications which require a material combining castability, strength, hardness and wear resistance with good thermal conductivity. For heavy electrical equipment, a high-conductivity beryllium copper that can be used at moderately elevated temperatures is required. A cast copper alloy with 0.5% Be, similar in properties to the high-conductivity wrought beryllium copper, is used for such applications.

Additions of 0.001% Be to magnesium alloys suppress the formation of magnesium nitride and permit the use of green sand molds, eliminating costly drying procedures. Small additions of beryllium (0.0005%) to aluminum alloys containing magnesium eliminate the tendency for magnesium compounds to separate and come to the surface of the melt with consequent rapid oxidation. Additions of 0.01 to 0.05% Be contribute to the thermal stability of aluminum alloys, refine the grain, and make them easier to cast. Higher amounts (up to 0.2% Be) further improve the castability and fluidity where intricate detail is required in aluminum castings. Other uses for beryllium in aluminum include the production of alloys with special discoloration resistance properties, as well as in aluminum hot dip baths for coating steels.

Beryllium nickel, an alloy containing 2.75% Be, is used to produce cast parts which can be heat treated to give good mechanical properties. It has a maximum carbon content of 0.5%, although there are others with a higher carbon content up to 1.10% that are easier to machine but have lower strength. The strength of beryllium nickel is most advantageously used when the design requires extremely high strength (175,000 psi. by water quenching from 1950° F. followed by 3 hr. at 950° F.) and hardness (up to Rockwell C-52) combined with good corrosion resistance. It has good wear and impact resistance, and its high fluidity in the molten state has led to use in producing small-detail investment castings such as pump propellers, mining drill bits, and miscellaneous aircraft components.

W. W. Beaver



how else would you make it?"

Now SEE and HEAR

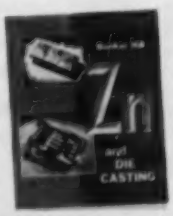
what Die Casting can do for you!

Every design and production engineer should see the new 16mm color and sound motion picture, "DIE CASTING – How else would you make it?". This brand-new picture not only establishes the relationship of die casting to other high-speed production methods, but it fairly presents the place of zinc among the die casting metals. Prints of the film, which runs 35 minutes, are available now for use by industrial organizations, technical societies, engineering colleges and government agencies. They can be borrowed free of charge from the producer of the picture, the American Zinc Institute, Inc., 60 East 42 St., New York 17, N.Y. *When writing, try to give several alternate dates for the showing.*

Once bookings for the film are accepted by the American Zinc Institute, arrangements can frequently be made through the cooperation of the American Die Casting Institute, a national association of jobbing die casters, to provide technical commentators and exhibits for film showings. A 28-page booklet entitled, "Die Casting – Molten Metal to Finished Part... Direct," which contains supplementary technical information, has also been prepared by the American Zinc Institute and will be made available for distribution among the audience following the film presentation.

The picture should be of interest not only to potential users of die castings, but also to manufacturers who are now using die castings in the assembly of their products. They will find the film helpful towards re-evaluating both the die casting process and the metal zinc in the light of the latest developments in this rapidly growing industry.

↑ *top*: Automotive defroster duct zinc die castings being removed from the dies in a die casting machine. These die castings are made at the rate of 750 sets an hour.
bottom: A 60-in. long, 22-lb. zinc die cast automotive radiator grille being removed from the die casting machine die prior to buffing and plating operations.
(The above photos are part of case history sequences taken from the film.)



READ "Bunker Hill Zinc and Die Casting"... the story of DIE CASTING as a high-speed, low-cost production tool... ZINC and its advantages as a base metal for die castings... BUNKER HILL'S contribution to the phenomenal growth of the die casting industry. This new 8½ x 11", 24-page publication is yours for the asking. Write for copy on your company letterhead please.

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SALES OFFICE FOR PACIFIC COAST NORTHWEST LEAD COMPANY SEATTLE, WASHINGTON

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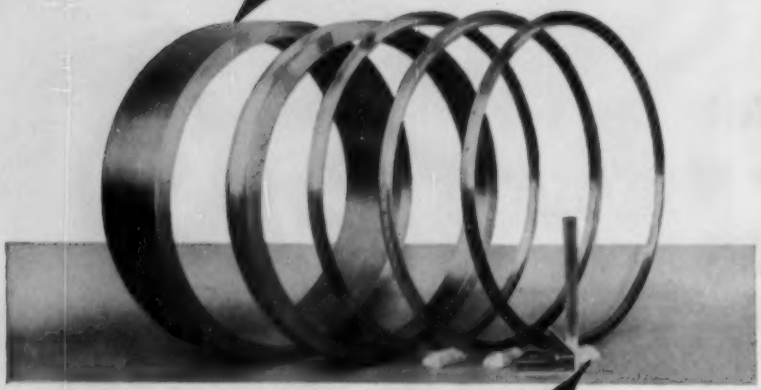

CUT and FINISHED by THE CUSTOMER

High Alloy rings for jet engines . . . we did the casting and rough finishing and the customer did the cutting and final finishing.

Centrifugally cast metal gives an exceptionally fine, dense, uniform grain structure. The strength of the metal approaches that imparted to a bar or ingot when it is hot forged. It produces an ideal metal for the tough service required of jet engine parts.

Incidentally, as evidence of our knowledge of and experience with tough alloy castings — static as well as centrifugal — the records show very few rejections by this engine manufacturer who subjected each of the many rings we furnished to his own very rigid tests.

May we suggest that you let Duraloy work on your high alloy castings — chrome iron, chrome nickel or nickel chrome? We have the experience and facilities for turning out high quality castings.

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CHICAGO OFFICE: 332 South Michigan Avenue

Air Gaging as a Measurement Tool*

Precision gaging of machined and ground parts by compressed air has been finding steadily increasing acceptance by industry over the past decade. It is economical, generally trouble-free and accurate, in addition to requiring only moderate operator skill. Present-day air gages have considerable versatility, being readily adapted to measurements of dimensions, flatness, squareness, concentricity, out-of-round and surface finish.

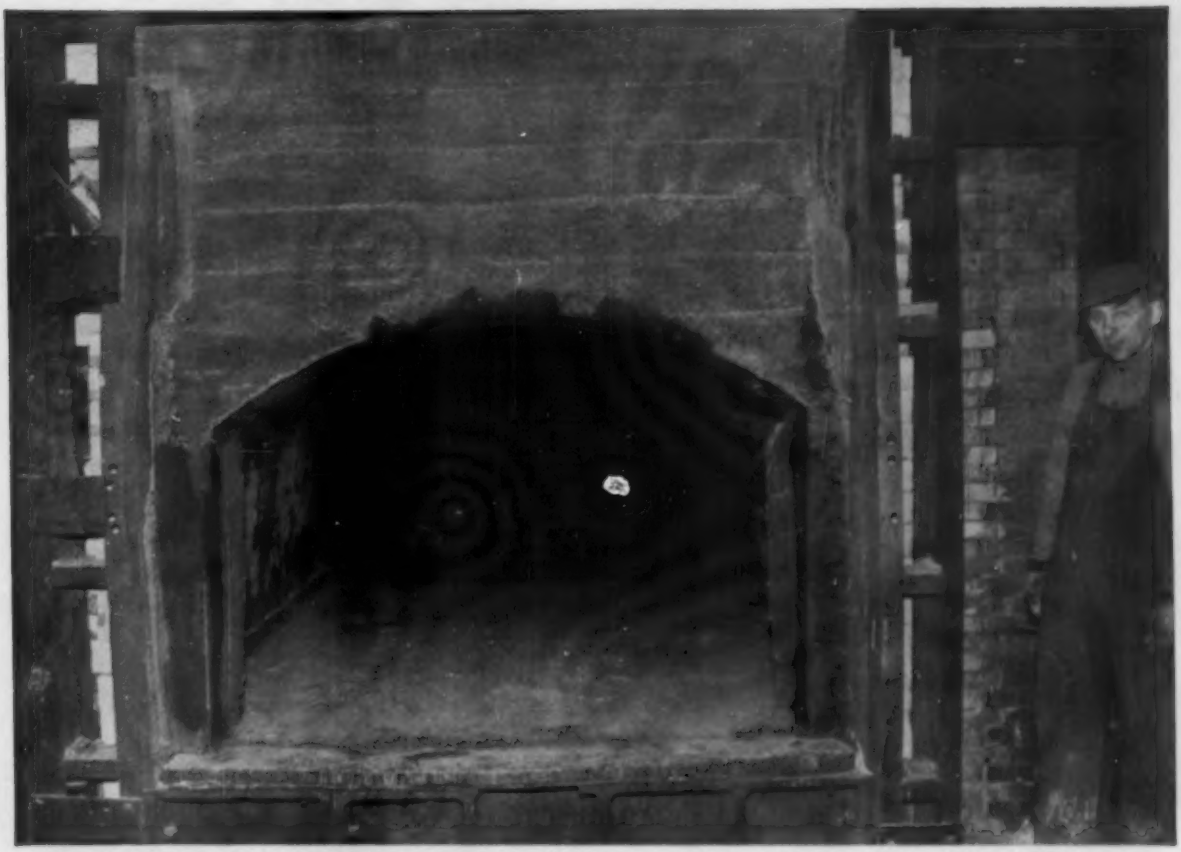
The two basic types of air gages differ only in the size-indicating mechanism used to show visually what is happening at the measuring air jet. One of these uses the flow system in which a flowmeter indicates variation in air flow caused by a change in distance from the surface being gaged to the measuring air jet. The other employs the back-pressure system in which a standard Bourdon tube or diaphragm dial gage is used to measure back pressure build-up that occurs when air flow from the measuring jet is restricted by the proximity of the part being checked.

Components of the latter system include, in order of direction of air flow, an air filter, pressure regulator, indicator for regulated pressure, a fixed restrictor orifice, back-pressure indicating dial and a gage head (or air jet) through which the air flow is directed at the surface of the workpiece. They are shown in Fig. 1 on p. 164. The restrictor orifice controls the quantity of air flowing in the pneumatic circuit between this orifice and the air jethead, this section being known as the back-pressure chamber.

In action, when a workpiece is positioned close to the gage head it somewhat restricts the free flow from this orifice. This results in air being received by the gage head from the restrictor orifice at a rate faster than it can escape, thus causing back pressure. The back pressure is indicated by movement of a pointer on the indicator dial. In turn this dial is

(Continued on p. 160)

*Digest of "Factors Involved in the Use of Air for Precision Measurement", by Charles W. Gardner, *General Motors Engineering Journal*, Vol. 1, November-December 1954, p. 16-21.



EASY-TO-CAST REFRACTORY CONCRETE forms front wall of in-and-out billet and slab heater at Industrial Forge & Steel, Inc., Canton, Ohio. Refractory Concrete gives trouble-free service despite furnace-crown temperatures of 2200-2250°F.

Here's how Refractory Concrete cuts installation time . . . improves performance

THIS BILLET HEATER front wall is only one example of the ways that Refractory Concrete serves Industrial Forge & Steel, Inc., Canton, O. Refractory Concrete is used on hearths for in-and-out furnaces . . . on charging floor areas for open-hearth furnaces . . . to line billet furnace doors and pre-heating pits. Placed in 5 hours, a refractory concrete bridge wall for a coal-fired boiler gave better service than previous walls that took 2 days to install!

You'll find that Refractory Concrete made with Lumnite* calcium-aluminate cement gives trouble-free service wherever heat, corrosion or abrasion are problems. It's easy to place—by plastering, pouring or cement gun—and it's ready for use within 24 hours.

For added convenience you can use a Lumnite-base castable mix—Lumnite cement plus aggregates selected for specific temperature and insulation needs. All *you* do is add water, mix and place. Castables are made and distributed by leading manufacturers of refractories. For more information, write Lumnite Bureau, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, New York.

INTERIOR VIEW of heater. Refractory Concrete made with Lumnite reaches service strength within 24 hours . . . takes temperatures up to 2600°F. and more.

OFFICES: *Albany, Birmingham, Boston, Chicago, Dayton, Kansas City, Minneapolis, New York, Philadelphia, Pittsburgh, St. Louis, Waco.*

**"LUMNITE" is the registered trade-mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.*

MP-L-103

ATLAS® **LUMNITE for INDUSTRIAL CONCRETES**

REFRACTORY, INSULATING, OVERNIGHT, CORROSION-RESISTANT

A UNIVERSAL ATLAS PRODUCT

UNITED STATES STEEL HOUR—Televised alternate weeks—See your newspaper for time and station.

AN OFFER OF HELP WITH YOUR HEAT PROCESSING PROBLEMS

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Continuous Brazing
Bright Annealing
Sintering Powder Metals
High Speed Steel Heat Treating
Billet and Bar Heating
Annealing
Melting in Crucibles
Forging
General Heat Treating

• **HERE AT HARPER,** the case history of your installation is written *before* you place your order!

The men of Harper believe in and work on this principle—you get the best results at lowest cost with high temperature electric furnaces specially designed and built to fit your products.

Isn't that better than trying to adapt your work to the furnaces? We call it "The Harper Way" and it works!

You need feel no hesitancy in leaning on Harper specialized *but broad* experience in developing electric furnaces for processing today's new metals and alloys—with or without special atmospheres.

The sketches show just a few types of Harper furnaces that are helping manufacturers gain a competitive edge through advanced design, volume production and lower costs.

Your request for a discussion is bound to spark-plug some worthwhile sharing of up-to-date thinking.

P.S. *You will not find us "high pressure".*

Furnace Builders Harper *for over 30 Years*

HARPER
Electric Furnace Corp.
40 RIVER ST., BUFFALO 2, N. Y.

Representatives in Principal Cities

Air Gaging . . .

calibrated so that when conditions of equilibrium are reached, it will read in terms of the distance from the part to the gage head orifice. For practical purposes, such equilibrium is considered to be reached instantaneously and any change in position of the workpiece is at once indicated on the dial of the air gage. Dimensional changes as small as 0.000010 (ten millionths) in. are readily measured.

Experience has shown that the following dimensions and pressures cover most applications: regulated air pressure, 25 to 60 psi.; gage head orifice diameter, 0.031, 0.052, 0.073 or 0.094 in.; restrictor orifice diameter, 0.013 to 0.067 in.; and number of air jets in combination, 1 to 3. Actually, restrictors are specified by the drill number size required to form each orifice. By limiting the number of gage head orifices to four a program can be set up to determine their characteristics, each in combination with 30 restrictor orifices, and for one, two and three gage heads. From these data curves were plotted to predict sensitivity and extent of linear range of gage head.

Sensitivity refers to the rate of change of back pressure with change in distance of the workpiece from the gage head; the greater the change, the greater the sensitivity.

Surface finish has a decided effect on size as determined by an air gage because the air jet spindle averages out the minute hills and valleys in the finish and indicates a slightly greater inside diameter than would, for example, a standard plug gage.

To overcome this effect, a gage spindle incorporating a floating lever was devised some years ago. It utilizes an open gage head in combination with a pivoted lever that contacts the surface being measured. Movement of this lever relative to the open air jet is measured by the gaging circuit. The floating lever pickup is recommended for surfaces with a finish over 50 rms.

The use to which the air gage will be put is an important factor in its design. Thus, if it is for 100% production checking, the ultimate must be provided in wear resistant

(Continued on p. 164)

Joe Vuille says it's simple arithmetic:
"180 cups per min. x 60 min. x 40 hours per week x 5 weeks =

2,160,000 brass cups in one uninterrupted run"

From the cup illustrated actual size above, socket shells are produced in eight operations on special equipment, followed by a stress-relief anneal and a final bright-dip.

Socket shell cups like this are formed in an 8-operation multiple-plunger press at the rate of 86 per minute.

Typical of Leviton's complete line of lampholders is the "Electrolier Push Thru" model. Both shell and cap are made of ANACONDA Brass.

For more than 20 years, Joe has been press-room foreman of Leviton Manufacturing Company, Brooklyn, N. Y., one of the world's largest manufacturers of electrical wiring devices.

Multi-million production runs of stamped and drawn products are nothing new to Joe, but he'll admit that there's more to it than a multiplication table:

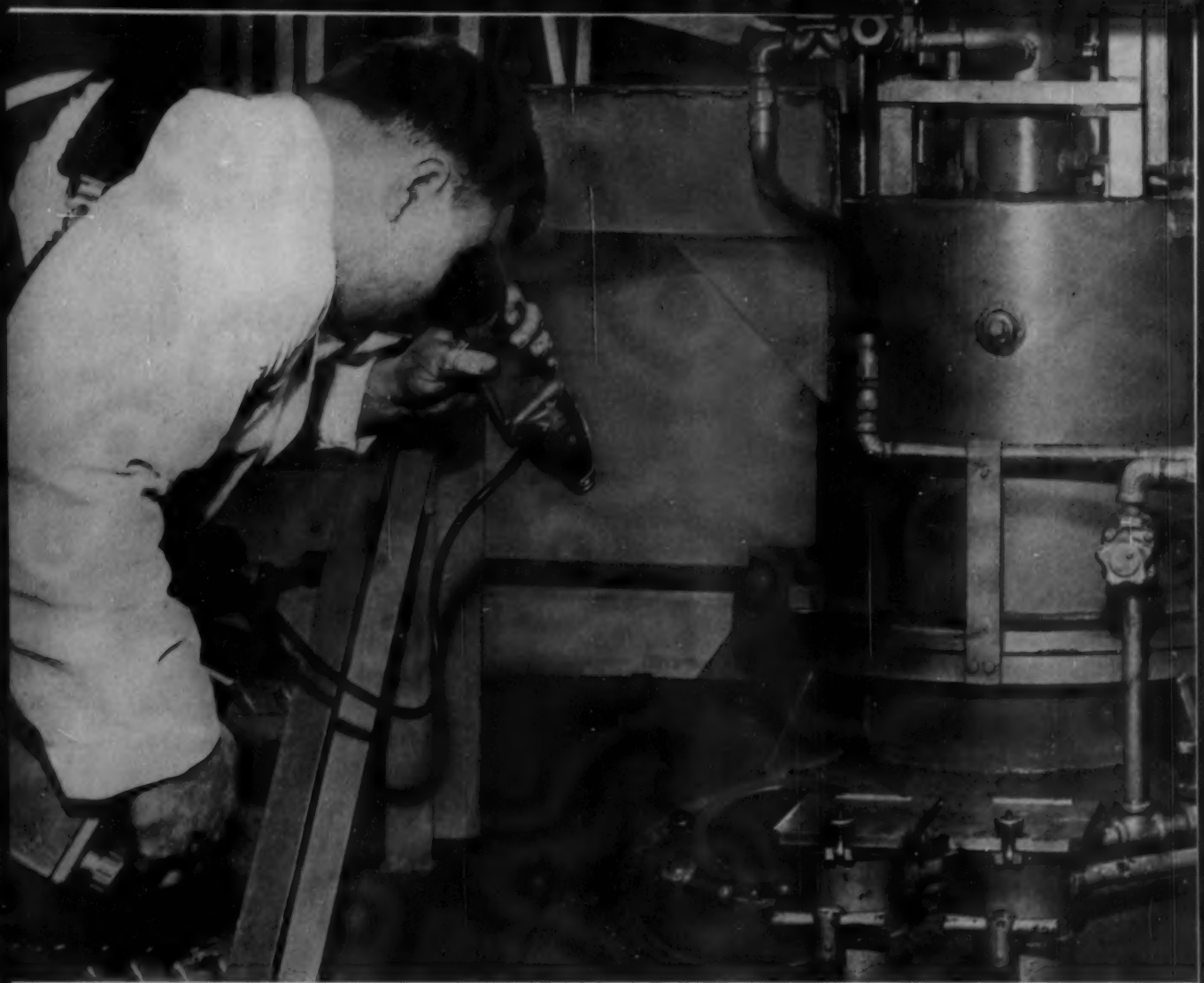
"First," says Joe, "you start with a good product design. Then the toolroom calls on its broad experience in diemaking. Next, good equipment and good housekeeping are essential in the pressroom. And then there's the brass: these extra-large coils of brass strip have to be just so . . . in dimension, composition, grain size, temper and surface finish . . . lot after lot after lot . . . tailor-made for the job."

Each year Leviton uses more than a million pounds of ANACONDA Brass, produced to Leviton's precise specifications, "just so . . . lot after lot after lot . . . tailor-made for the job." Perhaps we can perform a similar service for you? Write to *The American Brass Company, General Offices, Waterbury 20, Connecticut.* In Canada: *Anaconda American Brass Ltd., New Toronto, Ontario.*

You can always depend on

ANACONDA®

copper, brass and bronze

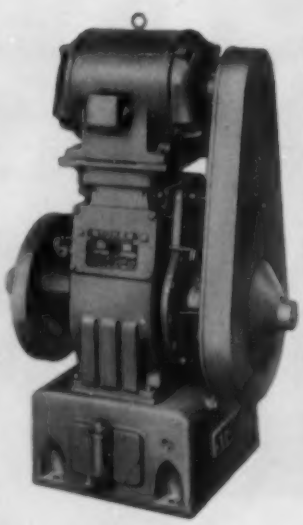


Operator at Thompson Products, Inc., Cleveland, Ohio, uses optical pyrometer to make a supplementary check on melt temperature in Stokes high-vacuum furnace.

THE COMPLETE LINE OF STOKES

Stokes manufactures a complete line of vacuum pumping equipment. This includes mechanical vacuum pumps, diffusion and booster pumps, vacuum valves and gages, and complete vacuum instrumentation. In engineered high vacuum equipment, Stokes builds vacuum metallizers, vacuum furnaces and other vacuum processing equipment.

Stokes has for many years been active in vacuum research. Vacuum experience among our engineers covers the range from laboratory equipment to some of the largest vacuum equipment in service. This experience is available to help solve your vacuum problems.



STOKES MECHANICAL VACUUM PUMPS

For vacuum processing systems and for maintaining low forepressures in high-vacuum systems, the Stokes Microvac pump provides efficient, economical operation. Designed with fully automatic lubrication and a long-lasting exhaust valve assembly, every Microvac pump is assured of smooth, trouble-free operation. Six sizes give capacities from 15 to 500 cfm. Send for catalog listed at right.

Thompson Products Uses

STOKES *Vacuum Furnace in Metals Research*

Thompson Products, Inc., of Cleveland, Ohio, one of the country's largest suppliers to the automotive and aircraft industries, carries on an extensive research and development program. To aid in the investigation of high-purity metals, Thompson has installed a Stokes high-vacuum furnace.

Thompson's vacuum furnace is currently rated at 200 pounds melt capacity: however, the unit is capable of 1000-pound production with only minor modifications, an important advantage should full-scale vacuum metal production be initiated.

Stokes is the leading supplier of production vacuum furnaces for industry. Outstanding features are a vacuum lock, which permits multiple melts and melt manipulation *without breaking vacuum;* high-capacity vacuum pumping systems, utilizing the new, high-speed Stokes Ring-Jet Booster pumps and the dependable Microvac forepump; and grouped controls for convenient operation. Stokes has many basic furnace designs – any of which can be modified to meet your particular needs.

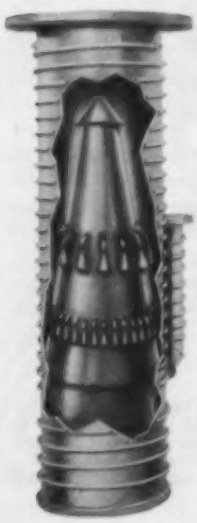
If you are interested in high-purity metals, you'll want to know more about Stokes high-vacuum furnaces for both laboratory and full scale production. Write for your free copy of Stokes Catalog No. 790, "High-Vacuum Furnaces."

F. J. Stokes Machine Company
5502 Tabor Road
Philadelphia 20, Pa.

SEND FOR TECHNICAL LITERATURE:

- Microvac Pumps—Catalog 750
- Diffusion and Booster Pump Specification sheets and performance curves
- The Story of the Ring-Jet Pump
- Complete Vacuum Processing Systems—Catalog 730
- How to Care for Your Vacuum Pump—Booklet 755
- Vacuum Impregnation—Catalog 760
- Vacuum Drying—Catalog 720
- Vacuum Furnaces—Catalog 790
- Vacuum Metallizing—Catalog 780
- Vacuum Calculator Slide Rule

VACUUM EQUIPMENT



STOKES RING-JET DIFFUSION AND BOOSTER PUMPS

The new Stokes Ring-Jet Pumps embody a new concept of the diffusion principle. Size for size, they have pumping speeds of 10% to more than 100% above any other diffusion pump for a given heat input. Ring-Jet Diffusion Pumps are available in sizes of 4, 6, 10, 14 and 16 inches; Booster Pumps in sizes of 4, 6, 10 and 16 inches. Send for information listed.

STOKES VACUUM VALVES

To control vacuum safely and surely, Stokes vacuum valves are available in 4, 6, 10 and 16-inch standard flange sizes.

STOKES-McLEOD VACUUM GAGES

For measuring vacuums from fractions of a micron up to 50 mm, Stokes-McLeod gages are the standard of reference. Four sizes available.

STOKES

OFFICES IN PRINCIPAL CITIES, REPRESENTATIVES THROUGHOUT THE WORLD

Air Gaging . . .

materials on all contacting surfaces. Carbide wear strips are common on the floating-lever type of gage.

Two factors can limit the accuracy of these air gages—dirt and wear in the air-gage pneumatic circuit. Air supply should be clean and dry to avoid eventual passage of dirt particles through the filter and plugging of restrictor and jet orifices. Also, if the part-locating details of the gaging fixture are allowed to wear beyond reasonable limits, the part-to-jet distance changes to a point where it is no longer within the linear range and inaccurate readings result.

A. H. ALLEN

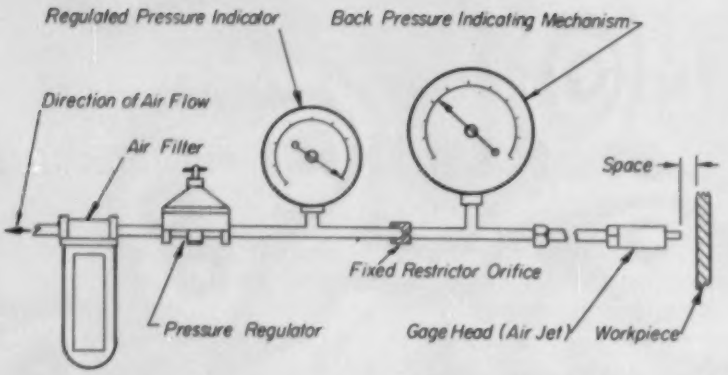


Fig. 1 – Schematic Representation of Back-Pressure Air Gage System. Section of the pneumatic gaging circuit between the restrictor orifice and the gage head is referred to as the back-pressure chamber

Standard or Special Design

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solve your heat-treating problems

Electrically heated, controlled atmosphere, rack-type magnesium alloy heat treat ovens.

Every Young Brothers Oven, whether standard type or special design, is engineered to meet the most exacting requirements. Leading manufacturers processing ferrous or non-ferrous metals are finding that Young Brothers Ovens improve the quality of their products at considerable savings in time and money. Many branches of the Armed Services, too, have approved the use of Young Brothers Ovens where heat treating applications are required.

For over 50 years, Young Brothers Company has continually developed batch and conveyor ovens for new processes, materials and products where heating requirements are not in excess of 950° F. The dependability of these ovens in thousands of installations is your assurance of finest results at lowest cost. Experienced engineers are available for consultation without obligation. Write for Bulletin 14-T on heat treating.

YOUNG BROTHERS COMPANY

Estab. 1896 1829 Columbus Road Cleveland 13, Ohio

Cracking in Steel Related to Temperature Changes*

BOILERS and other parts exposed to frequent temperature changes occasionally have cracks which cannot be accounted for by mathematical analysis of the mechanical stresses involved. Because these defects have been attributed to the effect of abrupt temperature changes, quench tests were used to verify this hypothesis.

The test specimens used were 150 mm. (about 6 in.) long, and 80 mm. (about 3 in.) in diameter, and had a bore diameter of 12 mm. (about ½ in.). The quenching was done by passing a fixed amount of the quenching medium (distilled water for most of the tests) through the specimens. The specimens were reheated after quenching, and the quench was repeated. After each piece had received a number of quenching treatments (at most 250), transverse and longitudinal sections were taken through the specimen, and the number, depth and (depend-

(Continued on p. 166)

*Digest of "Crack Formation in Low-Alloy Steels Due to Abrupt Temperature Changes", by Wilhelm Rädeker, *Stahl und Eisen*, Vol. 74, July 15, 1954, p. 929-943.

AS PARTNERS IN YOUR PROGRESS

...we have great confidence in you – our customers!

It is because we have this confidence in you that we substantially increased the production capacity of our Niagara Falls, N. Y. and Morganton, N. C. plants.

It is because of this confidence that we are constantly engaged in far-reaching research and developmental activities to insure your steadily increasing acceptance of our products in the years to come.

And it is because of this confidence in you that we look forward to still greater rewards from our partnership in your progress — to the degree that they are merited through the dependability of our products and the alertness of our service.

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Great Lakes Carbon Corporation

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Cracking . . .

ing on the number of quenching treatments) the penetration rates of the cracks originating at the inner quenched surface of each test specimen were measured. The temperatures from which the specimens were quenched varied between 390 and 1290° F. The compositions of the steels used in the tests are listed in the table alongside.

Analysis of Steels Tested for Crack Formation

Alloy	C	Si	Mn	Cb	Cu	Al	Mo	Ni
Mild steel	0.04	—	0.06	0.67	0.21	0.010	—	—
St 35	0.13	0.14	0.49	0.86	0.19	0.009	—	—
St 45	0.28	0.18	0.51	0.06	0.17	0.009	—	—
19 Mn 5	0.21	0.35	1.20	0.09	0.17	0.008	0.03	0.06
H IV A (fine grained)	0.22	0.39	1.34	0.09	0.20	0.018	—	—
Cu-Ni steel	0.23	0.35	...87	0.07	0.53	0.008	0.27	0.54
Roll steel	0.23	0.30	0.47	1.00	0.18	0.022	0.30	1.25
Gray iron*	3.52	2.16	0.48	—	—	—		

Phosphorus range 0.009 (mild steel) through 0.05% (19 Mn 5); sulphur range 0.017 (mild steel) through 0.042% (roll steel); nitrogen range 0.004 through 0.005%, except no nitrogen for H IV A and gray iron.

*3.36% graphite, 0.120% P, 0.52% S.

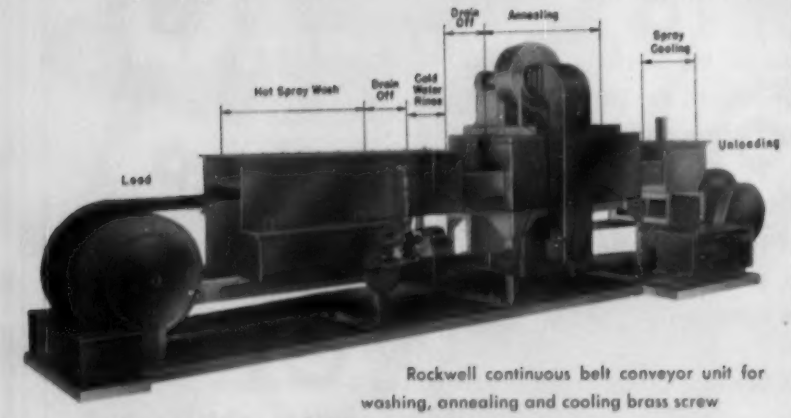
According to the experimental data, cracks begin to form at a temperature of 572° F. when the quenching medium is water. The number of cracks along the bore, as revealed by a transverse section of the test piece, reach a maximum for quenching temperatures between 750 and 930° F., the number of cracks dropping off at higher temperatures. The total depth of the cracks followed a similar pattern. A correlation was made of the number of cracks with the number of quenching treatments, and this showed that the number of cracks was already established after the first quench.

Quenching in salt solutions (sodium chloride or sodium sulphate) of various concentrations revealed that the effect of quench temperature on the number of cracks and the total depth of the cracks is the same as when distilled water is used, except that crack-formation begins at higher temperatures with the salt solutions. When quenching was done in a 32% calcium nitrate-ammonium nitrate solution, the total depth of the cracks appeared in the same temperature range but had a considerably higher value. The formation of cracks was delayed when corrosion products, caused by the quenching agent, formed on the quenched surface of the specimen.

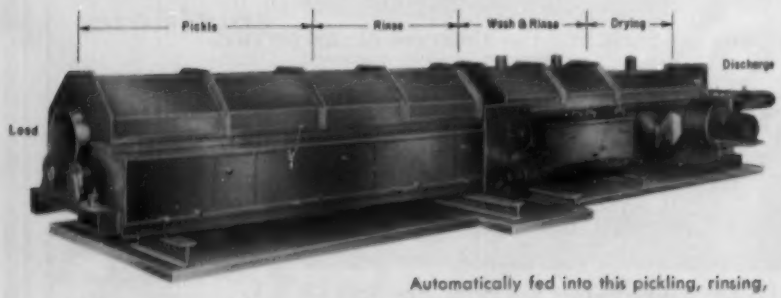
The extent of crack formation was found to be dependent on the rigidity of the specimen, and especially on the wall thickness. However, cracks were observed on specimens having a wall thickness as small as 4 mm. (about 0.16 in.) after quenching from 930° F.

R. C. Shnay

Continuous-Automatic-Efficient Cleaning • Annealing • Pickling



Rockwell continuous belt conveyor unit for washing, annealing and cooling brass screw bases for fuses, which are then . . .



Automatically fed into this pickling, rinsing, washing and drying machine—all Rockwell designed and built.

This unique system for continuous, automatic processing and annealing metal products is one of many Rockwell-built types, coordinated into time, labor and space saving equipment for uniform, economical production. Your inquiries invited.

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Photo shows automatic bolt maker. Courtesy of Oliver Iron & Steel Corporation.

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"It takes two to make a bargain"

How right!

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- Special cold heading inspection for good centers
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- Made specifically for cold heading applications
- Toughest grade of sintered carbide
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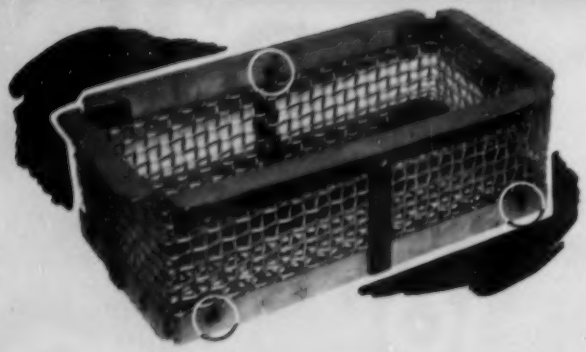

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✓ PROOF

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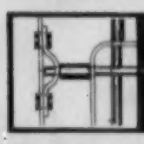
—Automobile manufacturer

✓ PROOF

"We've had no down-time since we started using Interlock."
—Machinery manufacturer



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Heat-Affected Zone in Arc Welded Type 347*

COLUMBIUM-stabilized stainless steel, known as A.I.S.I. Type 347, has creep and rupture properties superior to the unstabilized grades. Hence, it is commonly specified for weldments to be used in high-temperature installations because of its good weldability and corrosion resistance in the heat-affected zone without postheating.

Cracking in the heat-affected zone after welding of heavy sections or following some post-heat treatment is not uncommon. Cracks have appeared adjacent to welds from exposure to elevated temperatures. Under conditions of corrosion a "knife-line" attack has been observed in a narrow band in the heat-affected zone.

The heat-affected zone of arc welds consists of incremental regions, each with a slightly different thermal history, so that there is a continuous change in metallurgical structure and, usually, variations in properties. In order to correlate these properties with microstructure and thermal cycle it is necessary to have specimens which contain definite, uniform microstructures identical to those in the various incremental regions of the heat-affected zone.

The welding laboratory of the Rensselaer Polytechnic Institute has developed a time-temperature controller apparatus which, in an appropriate specimen, simulates the heating and cooling cycle of any part of the heat-affected zone. Thus, the properties of the microstructures in the zone may be determined.

The first step required in this operation is the determination of the various heating and cooling cycles occurring in the region between the weld bond and the unaffected basis metal. These thermal cycles are dependent upon plate thickness, heat input and the ambient temperature of the basis metal.

In this study thermal data were

(Continued on p. 170)

*Digest of "Some Properties of the Heat-Affected Zone in Arc Welded Type 347 Stainless Steel", by E. F. Nippes, H. Wawrousek, and W. L. Fleischmann, Report No. KAPL-1105 (March 1954), Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.

Twin Kemp Atmos Gas Generators Give This Steel Producer Absolute Atmosphere Control

Preventing oxidation and discoloration during the annealing of cold strip steel is the assignment of two Kemp Model 6-MR Atmos Gas Generators installed at Thomas Strip Division of Pittsburgh Steel. The picture shows Fred Michaels, Turn Foreman, observing the test burner on the panel of the controlled atmosphere producer.

Fueled with natural gas, these units supply uniform atmospheric gas within the annealing furnaces . . . deliver exact qualitative analysis regardless of load demand. Delivering up to 6,000 cfh, the battery of Kemp Generators assures protection against oxidation and discoloring of steel in process.

Kemp Units "Do Far Better Job"

Division management states that the Kemp Generators are doing a far better job than the generating equipment they replaced. Purity of the gas is very good by actual analysis . . . equipment capacity increased . . . maintenance and labor costs reduced . . . product quality improved by the much closer atmospheric control made possible by Kemp.

Kemp Can Help You

If you have a controlled atmosphere problem, Kemp can help you. Every Kemp Atmos Generator is engineered for fast-starting, easy operation . . . delivers a chemically-clean, controlled atmosphere at specific analysis, without fluctuations regardless of demand. For convenience, safety, and dependability—specify KEMP. A Kemp engineer will gladly discuss your own specific problem without obligation.

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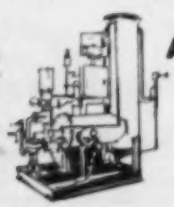

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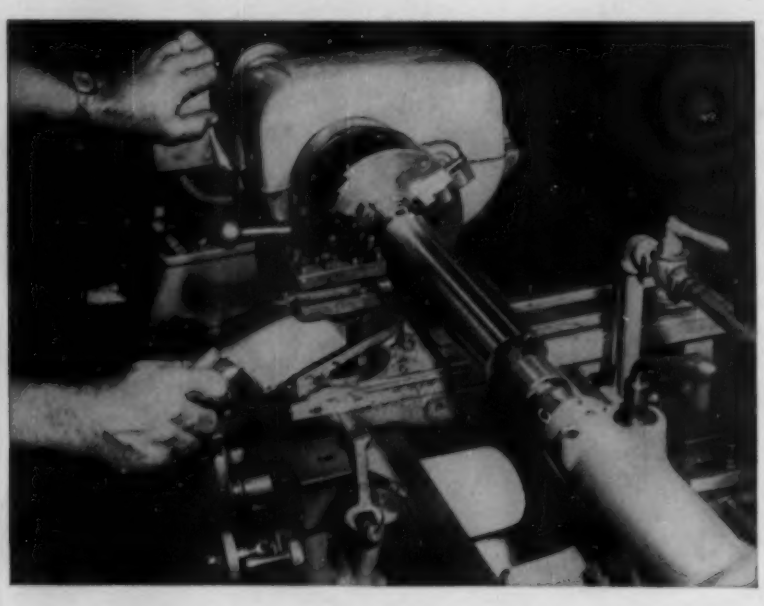

NEW ALLOYS easy to machine

PRODUCTION results and thorough research tests show that unalloyed titanium machines similar to 18-8 stainless steel. The alloy grades machine somewhat harder, but do not approach the difficult-to-machine high temperature alloys.

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For complete information, write for a copy of "Titanium Machining Recommendations". It is based on our broad experience as a leading producer of this lightweight, corrosion-resistant metal. Write Mallory-Sharon Titanium Corporation, Dept. F-5, Niles, Ohio.

MALLORY Ti SHARON

Heat-Affected Zone . . .

obtained on 1½-in. plate since, for metallurgical purposes, such data are considered applicable to any section thickness above 1 in. Energy input levels of 20,000, 30,000 and 45,000 joules per in. were used to deposit bead welds in grooves 1/16 in. deep by 3/8 in. wide in the plate. Thermal cycles for various locations in the heat-affected zone were determined by chromel-alumel thermocouples inserted in holes drilled from the back of the test plate. A 14-channel oscillograph recorded the output of the thermocouples.

These data are used in a series of mathematical computations utilizing a generalized equation expressing temperature distribution in the heat-affected zone as a function of time, distance from the weld centerline and welding factors, such as heat input and basis metal ambient. This equation has the following form:

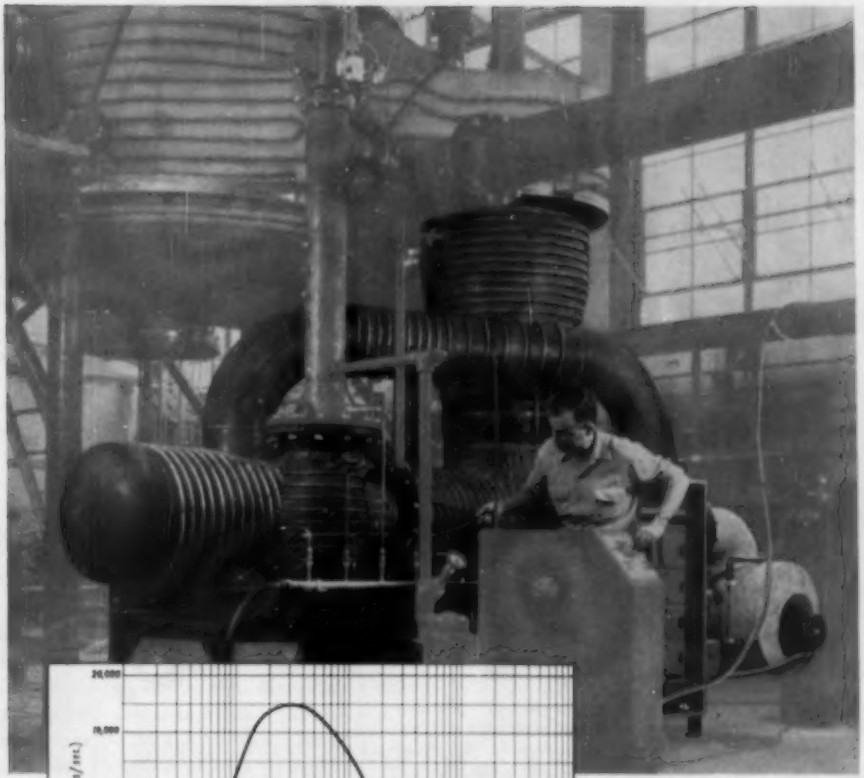
$$T - T_0 = \frac{F(s, d)}{1000} \times EI \times IF,$$

in which T is temperature (°F.) at distance d from weld centerline and at time s, after the arc passes; T_0 is temperature of plate when welded; F(s, d) is function of distance and time after the arc passes; EI is energy input in joules per inch of weld; and IF is input factor, which accounts for the effect of plate temperature (unity at room temperature; less for higher temperatures).

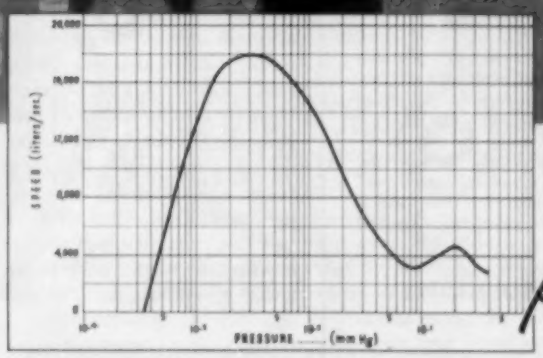
The computations involve plotting F(s, d) versus time for various distances d for each of the weld runs and also plotting F(s, d) versus distance for various times s. The values of F(s, d) are averaged and tabulated to show the values of F(s, d) versus d and s. These values are used to calculate the heating and cooling cycle for various specific peak temperatures in the heat-affected zone. A controller cam is constructed to reproduce each of these cycles in the temperature-time controller apparatus.

A limited number of tests were made with the controller using peak temperatures of 1800, 2000, 2200, 2400, 2475 and 2500° F., each representing the thermal cycle of a specific increment of the heat-affected zone of 1½-in. plate welded without preheat and using a heat input of 30,000 joules per in.

(Continued on p. 172)



The type KS-16,000 diffusion-ejector pump undergoing helium-leak check on a CVC one-thousand pound high-vacuum melting and casting furnace installation.



Type KS-16,000's performance curve.

Pressure falls fast

with this new CVC high-vacuum pump

Removing *1,000,000 micron-liters of gas a second* from a furnace chamber—that's the task of *CVC's* new diffusion-ejector pump, type KS-16,000.

1,000,000 micron-liters a second, or 12.5 pounds of air per hour, means that this *single* pump can exhaust a one-thousand pound melting and casting furnace smoothly and swiftly and maintain the desired operating pressure throughout outgassing periods.

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This high-speed, high-vacuum pump is the latest in a series of advances made in the *CVC* laboratories—advances helping to make vacuum metallurgy an accepted and profitable production process.

Other features of the type KS-16,000:

1. Speed for air is 18,000 liters a second at 4 microns Hg (see chart). Speed for hydrogen is 42,000 liters a second at 6 microns Hg.
2. Ultimate pressure is 4×10^{-4}mm Hg.
3. Limiting forepressure is 10mm Hg.
4. Clearance between jets and pump casing is extra wide and unobstructed. *Dust particles found in various metallurgical processes will not clog jet action.*

For further information about the type KS-16,000 or about the use of high vacuum in metallurgy, write to ***Consolidated Vacuum Corporation, Rochester 3, N. Y.*** (a subsidiary of ***Consolidated Engineering Corporation, Pasadena, California***).

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Heat-Affected Zone . . .

The as-received material was fine-grained with the carbide phase well dispersed in dot form. Peak temperatures of 2000 and 2200° F. caused no obvious change, but considerable grain growth and disappearance of carbides was caused by peak temperatures of 2475 and 2500° F. Some evidence of grain growth was found at a peak temperature of 2400° F.

A subsequent sensitizing thermal treatment of 1200° F. for 2 hr. enabled delineation of grain boundaries by etching in specimens that had been originally heated to peak temperatures as low as 2000° F., whereas the grain boundaries in the as-heated specimens could be etched only faintly.

Corrosion tests in boiling 65% nitric acid solution for five 48-hr. periods (fresh solution for each period) showed that the heat-affected zone in the as-welded condition was not attacked; that is, corrosion rate (A.S.T.M. standard conversion) is independent of peak temperature. After sensitization, the corrosion rate is only slightly greater for samples exposed to peak temperatures of less than 2400° F. but becomes considerable for samples exposed to peak temperatures of 2400° F. and higher. The corrosion attack is intergranular.

The impact tests of as-welded specimens showed no appreciable change of room-temperature toughness (145 to 155 ft-lb.) except for a slight drop (to 130 ft-lb.) for a peak temperature of 2475° F. No impact tests were made of the sensitized specimens.

It was observed that the dot carbides begin to go into solution at a peak temperature of 2200° F. and are completely in solution above 2400° F. Incipient melting at the grain boundaries at 2500° F. terminates grain growth. This grain-boundary precipitate is most sensitive to corrosion and occurs in a narrow band of the heat-affected zone extending about 0.05 in. from the bond in a weld of 30,000 joules heat input on 1¼-in. plate. Kinzel has suggested that the corrosion may be due to a high degree of strain at the precipitate interface created by a lack of registry.

While the room-temperature im-

(Continued on p. 174)

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"NO FAILURES

SINCE USING

SAVES MONEY, TOO!"

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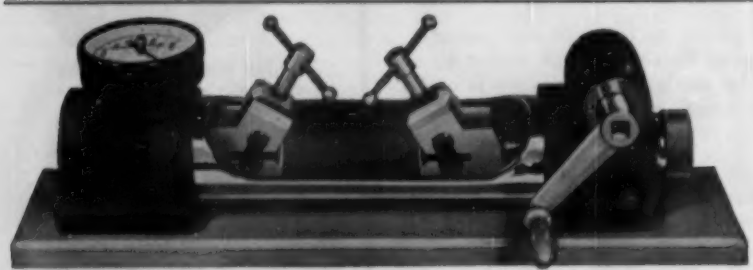

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Heat-Affected Zone . . .

pact strength of the heat-affected zone is not appreciably different from that of the basis metal, the rupture strength of the region heated to a peak of 2400° F. showed a considerable loss of ductility.

W. L. WARNER

Contaminants in Arc Welding Titanium*

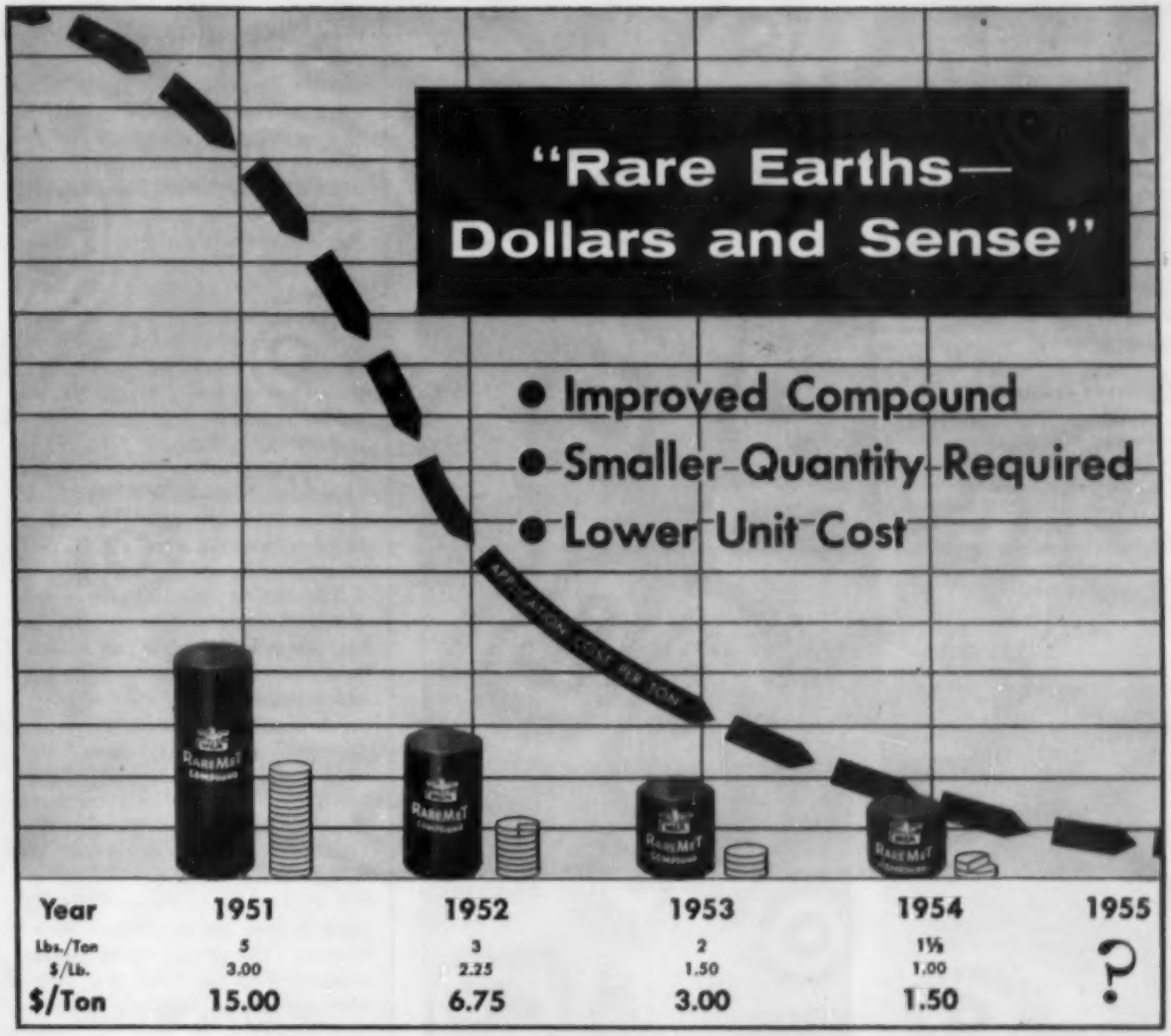
THIS is a summary of the work done at the Bureau of Mines to determine the effect of small quantities of oxygen, nitrogen, air and water vapor in the shielding atmosphere used for the tungsten arc welding of commercially pure titanium. Earlier work, published in *Welding Research Supplement*, Vol. 32, No. 6, 1953, p. 238s to 291s, reported the effects of oxygen and nitrogen present in quantities greater than 1%, and moisture greater than 5% humidity. The present paper describes the results obtained in extending this investigation to include atmospheres containing 0.25 to 1% oxygen, nitrogen and air, and 2.5 to 10% relative humidity. Tensile, bend, hardness and Charpy impact results are reported.

All joints were made in a welding chamber using helium as the primary shielding gas. The welds were made automatically at speeds of 5 to 6 in. per min. on material ⅛, ¼ and ½ in. thick. Where filler metal was used, it was cut from the sheet being welded. For the two heavier gages, multiple passes were used.

The results obtained with helium atmospheres containing oxygen show the tensile behavior to be unaffected until the oxygen content of the atmosphere reaches 1%. This is probably due to the fact that tensile failure at lower values of oxygen occurred in the parent metal, and the values obtained, therefore, reflect primarily parent metal properties. The bend and hardness tests indicate more accurately the progressive in-

(Continued on p. 176)

*Digest of "Effect of Atmospheric Contaminants on Arc Welds in Titanium", by J. C. Barrett and I. R. Lane, Jr., *Welding Research Supplement*, Vol. 19, March 1954, p. 121s-128s.



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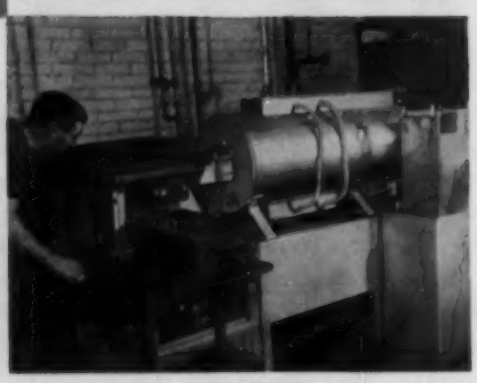

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Welding Titanium . . .

crease in hardness and loss of ductility as the amount of oxygen in the protective atmosphere is increased. As little as 0.25% oxygen significantly affects weld hardness and ductility. In the heavier gages, as the number of weld passes was increased, these effects became more pronounced.

The embrittlement resulting from nitrogen as the atmosphere contaminant is somewhat more severe than from oxygen, although the results follow the same general pattern. A nitrogen content of 0.25% in the shielding atmosphere markedly reduces even the tensile ductility of the ¼-in. thick welds. Bend and hardness tests show the detrimental effect of nitrogen in all welds.

The data on the effect of moisture (from practically nothing to 2.53 mg. per l., at 80° F., or 10% relative humidity) indicate that moisture has only a slight influence on weld properties. Bend and tensile values are apparently unaffected, although the weld hardness was increased slightly. Since the bend tests on ¼-in. sheet at a bend radius twice the thickness of the sheet showed no failure, some bends were made at 1 T bend radius. In this test the weld made in pure helium did not break, whereas the other three welds cracked. This illustrated that moisture does lower ductility, but only very slightly.

The effects of small amounts of dry air on the welding of ⅜-in. thick stock gave similar results to those obtained with oxygen and nitrogen. The bend values show the progressive loss of ductility as the contaminant level is increased.

A comparison of the Charpy impact values obtained for welds made in pure helium, in helium plus 0.25% hydrogen, in helium containing 1.23 mg. moisture per liter, and the longitudinal parent metal reveals very little change in impact values for these welding atmospheres at testing temperatures of 32, 105, 250 and 320° F. (except for the parent metal at 320° F. which is significantly higher than the welds). It would appear from these results that welding itself does not markedly alter the impact properties. The data show that oxygen or nitrogen present even to the extent of 0.25% in the shield-

ing atmosphere does significantly reduce the impact values observed. It is important to note also that hardness traverses of the ½-in. thick welds showed the surface to be more heavily contaminated than the center of the weld. In machining the Charpy specimens, the highest hardness material was therefore removed.

The authors draw the following conclusions from their work:

"1. Welds in titanium up to ½ in. thick made in an atmosphere of pure helium have tensile and bend properties comparable to those of the parent metal. The lowering of weld impact properties is not any greater than one would expect on changing from a wrought to a cast structure.

"2. Nitrogen, oxygen and dry air adversely affect the properties of titanium welds when their volume percentage (singly) is as low as 0.25% of the welding atmosphere. Heavier gages are more sensitive to oxygen and nitrogen, as the last weld passes cover a large surface. Impact strengths, as well as bend properties, are considerably lowered by small volume percentages of these contaminants.

"3. Small amounts of hydrogen and moisture in the welding atmosphere have little effect on weld properties, including impact strength." D. R. Luster

Causes of Catalytic Corrosion*

It had previously been observed that a disintegration of the surface sometimes occurred on platinum or palladium that was used to catalyze a chemical reaction. This phenomenon has been called *catalytic corrosion*. In the known instances of catalytic corrosion the chemical reaction had been exothermic, and thus the possibility existed that local overheating was a factor in producing the corrosive action. Therefore in the present research a study was made of an endothermic reaction (the decomposition of ammonia, $2NH_3 \rightarrow N_2 + 3H_2$) in which this complication would be avoided.

The test materials were iron, copper and platinum. The polished

*Digest of "Catalytic Corrosion", by S. Z. Roginskii, I. I. Tret'yakov and A. B. Shekhter, *Doklady Academii Nauk SSSR*, Vol. 91, 1953, p. 881-884.

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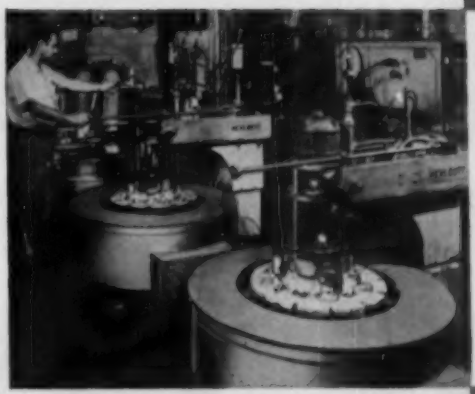

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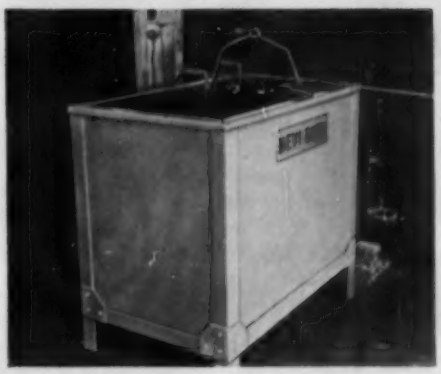

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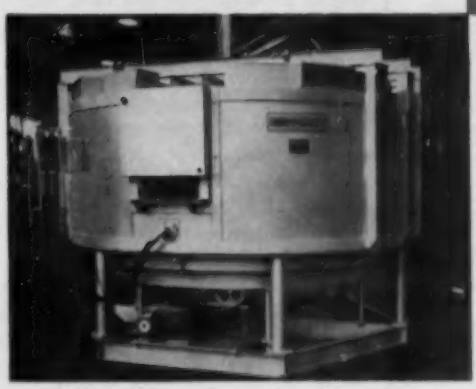

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metal was exposed to a stream of ammonia at atmospheric pressure and at a sufficiently high temperature to cause some decomposition of the ammonia. Electron micrographs revealed the changes that were produced on the surface of the metal.

The polishing scratches on the iron were completely obliterated after a 10-min. exposure to the ammonia at 1150° F. and the surface took on an appearance of friable porosity. This result showed there was a strong disintegration of the surface of the catalyst even for an endothermic reaction. Next, the iron was exposed for 1 hr. at the same temperature to the equilibrium gas mixture, which contained only 0.042% ammonia. This treatment caused a further change in the structure of the surface, showing that the equilibrium was a dynamic one with decomposition of the ammonia occurring at some points and recombination occurring at others.

When copper was exposed for 1½ hr. at 1470° F. the polishing scratches were obliterated and the grain boundaries were sharply revealed. The amount of disintegration varied markedly from grain to grain. In spite of the higher temperature used in this test, the rate of disintegration was less than for iron. The exposure of platinum to 1650° F. for 7 hr. also revealed the grain boundaries. However, as the polishing scratches disappeared, there appeared in certain grains a set of parallel streaks with a spacing of 0.3 micron. The rate of disintegration of platinum was less than that of copper.

Control tests showed that neither hydrogen nor nitrogen could separately produce the disintegration of iron or copper. A slight effect produced on platinum was attributed to impurities. Neither the rate of self-diffusion of the metal nor the amount of decomposition of the ammonia could be correlated with the degree of catalytic corrosion observed on the various metals. It was decided as being likely that an iron nitride had formed and that neither copper nor platinum could form a nitride. The investigators concluded that compound formation was the most probable cause of a high rate of catalytic corrosion and also as that it would cause the metal to become a catalyst.

(Continued on p. 180)

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Catalytic Corrosion . . .

Even in exothermic reactions it was considered unlikely that local overheating was the leading cause of catalytic corrosion. Three possibilities that seemed more likely were: *(a)* increased mobility of the surface atoms of the metal as a result of the catalytic reaction; *(b)* increased mobility because of sorption of a gas, such as ammonia or hydrogen, a sorption not connected directly with the catalysis; *(c)* the formation of a new phase under the conditions of catalysis. These three causes were considered to have contributed in varying degrees to the catalytic corrosion of the three metals studied.

A. G. Guy

Corrosion of Aluminum Alloys*

Numerous field tests were made to assess the corrosion behavior of Al-Cu-Mg and Al-Mg-Si alloys in atmosphere and salt and river waters. The samples were exposed for two years in nine different localities and then were examined and also tested for tensile strength. A second group of specimens was stretched 5% before exposure. The two alloys used were H 10-W.P. (0.68 Mg, 0.98 Si, 0.27 Fe, 0.04 Cu, 0.04 Mn) and H 15-W.P. (3.8 Cu, 0.74 Mg, 0.54 Mn, 0.95 Si, 0.25 Fe, 0.02 Ti). The aging treatments were 8 hr. at 350° F. for H 10-W.P. and 8 hr. at 340° F. for H 15-W.P., the H 10-W.P. being die quenched, and the H 15-W.P. being quenched after solution heat treatment. A channel section measuring 1¼ x 1 x 1 in. and 0.1 in. thick was extruded from normal batches of the alloy billets. The extrusions were made by the normal production method.

Microscopic examination showed the corrosion of the H 10-W.P. alloy to be usually of the intercrystaline type, varying in intensity in the various exposures. In spite of the two years of corrosive attack, the tensile strength ranged from 31,000 to 42,000 psi., which represents an average loss in strength of only about 3000 psi. The H 15-W.P. alloy was more severely attacked and this attack was frequently of the foliation type. The tensile strengths of the stressed samples of both alloys did not indicate an increase in corrosion attack. For the H 15-W.P. this is attributed to structural inhomogeneities which produce planes of preferential corrosion attack parallel to the surfaces of the extrusion. Any corrosion pits and fissures which start from the surface fail to exert any stress-raising effect because they are turned parallel to the surface and to the direction of stressing along these planes of inhomogeneity. The samples exposed at the Sheffield site had a greater loss of strength after two years than is reported for 51 S after three years' exposure at Altoona, Pa. (E. H. Dix, Jr. and R. B. Mears, A.S.T.M. Symposium on Tests on Nonferrous Metals, Vol. 57, 1946). The corrosion rate decreased with time.

H. J. Roast

*Digest of "Atmospheric Corrosion and Stress-Corrosion of Aluminium-Copper-Magnesium and Aluminium-Magnesium-Silicon Alloys in the Fully Heat Treated Condition", by G. F. Metcalfe, *Journal* of the Institute of Metals, Vol. 81, February 1953, p. 269-277.

Weldability of Low-Alloy Vanadium Steels*

This reports the work done by the British Welding Research Assoc. on the weldability of two high-tensile steels (manganese-nickel-chromium-molybdenum) in which part or all of the molybdenum is replaced by vanadium. (The reader should review the results reported in two previous abstracts, *Metal Progress* for September 1954, p. 200 and November 1954, p. 174.)

The weldability was assessed in terms of the resistance to crack formation in the heat-affected zone adjacent to a restrained weld under controlled conditions of cooling. The Controlled Thermal Severity (C.T.S.) test was used (described by Cottrell in *Welding Journal Research Supplement*, Vol. 18, June 1953). In the present tests, three grades of cooling severity were chosen: Thermal Severity Numbers (defined by Cottrell in the reference mentioned previously) 4 and 6 were

(Continued on p. 182)

*Digest of "Weldability of Twelve Low-Alloy Steels Containing Vanadium", by B. J. Bradstreet, *Welding Research*, Vol. 7, October 1953, p. 107-110.

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Weldability . . .

obtained using ⅜-in. thick top and bottom plates, and T.S.N. 14 using ⅜-in. top plate on a 1⅜-in. bottom plate, using only the trithermal weld position.

The 12 experimental steels, made in 20-lb. induction melts, were forged into 15 × 4 × ⅜-in. plates. The cast analyses of the 12 steels, together with those of steels A and B, are given in Table I. Low-hydrogen mild steel electrodes were used. Other details of welding procedure may be found in the paper. The welds were sectioned not earlier than a week after welding to allow time for the formation of hard-zone cracks. Hardness tests were made through the welds and macrosections were polished and etched for the detection of cracks. Table II gives a summary of the results of the test.

It was concluded that replacement of molybdenum by vanadium in a low-alloy steel, such as A, improves the mechanical properties for the normalized and tempered condition without unduly affecting

(Continued on page 184)

Table I — Cast Analyses of Experimental Steels

Steel No.	C	Mn	Si	Ni	Cr	V	Mo
1	0.12	0.57	0.11	0.75	0.87	0.22	—
2	0.17	0.69	0.11	0.70	0.90	0.22	—
4	0.15	0.78	0.09	0.73	0.92	0.14	—
5	0.18	0.74	0.05	0.83	0.88	0.14	—
7	0.16	0.86	0.18	0.79	0.97	0.14	0.19
8	0.17	0.59	0.20	0.78	0.95	0.14	0.19
10	0.20	1.24	0.16	0.10	0.71	0.23	—
11	0.17	1.23	0.15	0.10	0.70	0.19	—
13	0.15	1.21	0.16	0.14	0.68	0.18	—
14	0.13	1.13	0.14	0.12	0.69	0.12	—
16	0.16	1.08	0.06	Trace	0.69	0.15	0.15
17	0.15	1.13	0.13	Trace	0.62	0.13	0.13
A	0.14	0.89	0.18	0.56	0.93	—	0.22
B	0.14	1.14	0.30	0.23	0.66	—	0.24

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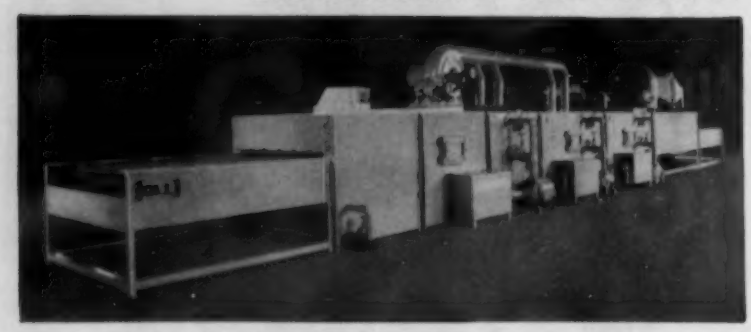

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its good weldability with low-hydrogen electrodes. The steel which gave the best combination of weldability and mechanical properties was one containing approximately 0.17% C, 0.70% Mn, 0.70% Ni, 0.90% Cr, 0.22% V, with a yield stress of 77,800 psi. when ¾-in. thick plate was normalized and tempered.

This investigation confirms the findings of many in this country of the beneficial effects imparted to low-alloy steel by vanadium by increasing the yield strength of normalized or normalized and tempered steels without impairing weldability. From the fundamental data reported it would appear that all of the molybdenum could be replaced by 0.14% or more of vanadium without imparing either the mechanical properties or the weldability. The 0.22% V steel gives slightly higher yield strength than the 0.14% V and one would have to balance the gain against the added cost.

Table II – Summary of Results

Steel No.	Yield, Psi.	T.S.N.*	Cracking†
1	62,700	14	0
2	78,500	6	0
		14	<1
4	74,600	14	0
5	72,600	6	0
		14	4
7	95,500	6	0
		14	47
8	101,200	4	0
		6	76
		14	71
10	72,000	4	0
		6	73
		14	23
11	72,600	6	0
		14	2
13	65,600	6	0
		14	33
14	62,000	14	0
16	78,900	6	0
		14	76
17	78,300	6	0
		14	28
A	69,900	18	6§
B	66,600	(Reeve test)	5§

*No cracking occurred on tests made with lower Thermal Severity Numbers than those listed.

†Per cent average cracking in vertical leg.

§Welding tests on steels A and B were conducted on a Reeve test assembly so as to produce severe conditions.

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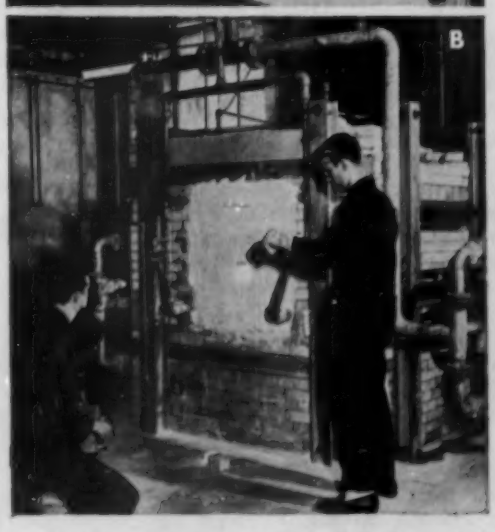

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But other finishes offering similar advantages over anodizing have entered the market. So . . . the current battle for acceptance. By any cost comparison Iridite #14 is the most economical. However, corrosion tests by users show contradictory results as to performance from Iridite #14 and other leading protective finishes for aluminum. Most tests show Iridite #14 superior, but some do not. The margin of difference, however, is always small. The truth is that all have proved good. However, our laboratory research indicated that still further improvements could be made.

That knowledge . . . plus our aim to give you even better protection and maintain the leadership of the industry, is exactly why Allied Development Engineers have been working for long years to develop a better finish than any of those now available, including our own Iridite #14.

Now the new finish is ready for you. It's called Iridite #14-2 (Al-Coat).

From a performance standpoint, Iridite #14-2 gives you two important advantages in the protective finishing of aluminum.

FIRST: in its fully colored brown film stage it provides corrosion resistance decidedly superior to previous processes.

SECOND: the basic brown film can be hot water bleached to produce a clear-type film with protection heretofore unobtainable from clear-type chemical finishes.

From an operating standpoint, new Iridite #14-2 gives you three important advantages.

FIRST: it provides consistently higher corrosion resistance for different aluminum alloys treated in the same bath.

SECOND: it provides a more uniform appearance for parts of different alloys and with varied surface finishes before treatment.

THIRD: its operating and technical characteristics are superior to those of other processes.

If you are using or planning to use a chemical finish for aluminum, you should have full details on new Iridite #14-2. Write us or send samples for free test processing. Or, for more immediate advice, call your Iridite Field Engineer. He's listed under "Plating Supplies" in your classified telephone book. - - - ALLIED RESEARCH PRODUCTS, INC., 4004-06 EAST MONUMENT STREET, BALTIMORE 5, MARYLAND.

P. S. Even new Iridite #14-2 will be constantly measured against both your needs and competitive processes to make sure you get the best possible, most economical finish for your product that man and the laboratory can develop.

NICKEL-LUME

FOR BRIGHT NICKEL BARREL PLATING

The H-VW-M Nickel-Lume Barrel Plating Process is ideal for producing bright-from-the-barrel decorative nickel coatings on small automotive parts, jewelry, novelties, nail clippers, files, hardware, fasteners, screws, and similar items. The new process is an application of Nickel-Lume, which made its appearance a year ago as an outstanding development in a bright nickel for rack plating.

Barrel installations have been in operation in the field for some time with many enthusiastic users. An important feature of this bright-nickel barrel process, is the consistency of color maintained even in recessed areas, as in hard-to-plate threaded parts. Subsequent chromium plating can be handled with ease since the nickel deposit is very active and, unlike many bright barrel processes, is not brittle.

Advantages of Nickel-Lume Barrel Plating are:

Uniform Brightness—deposits, right out of the barrel, are uniformly bright with a pleasing "clean," white color even in hard-to-plate areas.

Low Stress—deposits are ductile and have a low compressive or tensile internal stress.

Activation Not Required—no activation is required between the nickel and chromium or other subsequent deposits.

High Tolerance To Impurities—organics are tolerated in greater concentrations than in other bright baths.

Complete Control—complete analytical control of all constituents.

Wide Operating Range—current density and temperature have a wide range with no resultant loss of brightness.

Good Corrosion Resistance—nature of the addition agent plus constant deposit characteristics give a high level of protection to the plated surface.

Stability—not a "fussy" bath—remarkably stable over long periods of operation.

Nickel-Lume for Barrel Plating is the direct result of continuous research conducted at H-VW-M . . . another example of Platemanship in action. Complete details and a new instruction manual will be forwarded on request.

PLATEMANSHIP

Your H-VW-M combination—of the most modern testing and development laboratory—of over 80 years experience in every phase of plating and polishing—of a complete equipment, process and supply line for every need.

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H-VW-M

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Lower costs through quality and speed . . . that's Airco's answer to your production problem – even when the materials include aluminum, bronze, copper, nickel, stainless steel . . . all engineering metals.

The Aircomatic welding unit, for example, was researched and designed by Airco to produce top-quality welds . . . especially in "problem" metals and alloys without flux . . . with minimum plate edge preparation and little or no preheat. In performance, Airco's Heliwelding is similar – though engineered for high-speed welding of *thin* sections of metals – any metals.

And with the newest Airco addition to inert-gas-shielded welding, Aircospot, you can weld from one side of the joint – eliminating jigs and backup plates. Aircospot is the perfect primary tool for fabrication and no finer cost-saving tool for tack welding has ever been devised.

You'll want to learn more about how Air Reduction's inert-gas-shielded arc welding processes can serve you. Contact your nearby Airco Representative, Authorized Airco Dealer – or write Airco direct.

WELDING SHOW VISIT BOOTH 254

AIRCO

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Divisions of Air Reduction Company, Incorporated, with offices in most principal cities

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Products of the divisions of Air Reduction Company, Incorporated, include: AIRCO – industrial gases, welding and cutting equipment, and acetylenic chemicals • PURECO – carbon dioxide, liquid-solid ("DRY-ICE") • OHIO – medical gases and hospital equipment • NATIONAL CARBIDE – pipeline acetylene and calcium carbide • COLTON CHEMICAL COMPANY – polyvinyl acetates, alcohols and other synthetic resins.

Metallurgical Aspects of

GAS-AIR FLAME HARDENING

Fig. 1

Gas-air flame hardening, applied to numerous components, such as gears, pinions, rollers, shafts, cams, wheels and cylinders, has proved to be the most economical production method for developing greater strength and longer life for critical service. This hardening method, using regularly-supplied fuels (manufactured gas, natural gas or propane) with air to support combustion, permits localized heating, closely controllable, to develop full surface hardness and controlled depth of hardness.

A Selas gas-air flame hardening unit typical of those being used by commercial heat treating establishments and by heat treating departments of industrial plants is shown in fig. 1. In this illustration a shaft pinion has been heated for hardening of the teeth. The operation is complete after quenching and tempering. In most hardening units of this type, quench tanks (oil or water) are located directly below the heating station to permit a rapid transfer of the work-piece to produce the required hardness established by the heat pattern.

For this and similar large work-pieces (to 40″ diameter and 5″ face width) it is generally required that surface hardening over the tooth area extend to a substantial depth. Gas-air burners permit this heat penetration without overheating of the surface metal. Transition of hard surface metal to softer core metal is gradual, minimizing residual stress concentrations. The treatment thus develops a hard, wear-resistant surface with a tough, shock-resistant core for critical service applications.

Gas-air flame hardening is also applicable to small work-pieces where development of a proper heat pattern requires more precise control of the heating and quenching. Fig. 2, a macro-etch of a section through a small gear (3″ O.D. by ¼″ thick), illustrates this type of hardening. The photomicrographs indicate full hardening of the teeth and hardening to a shallow depth at the root of the teeth. This pattern is highly desirable in preventing a common type of failure, breakage of the root, which is a bending fatigue failure, usually starting in the fillet

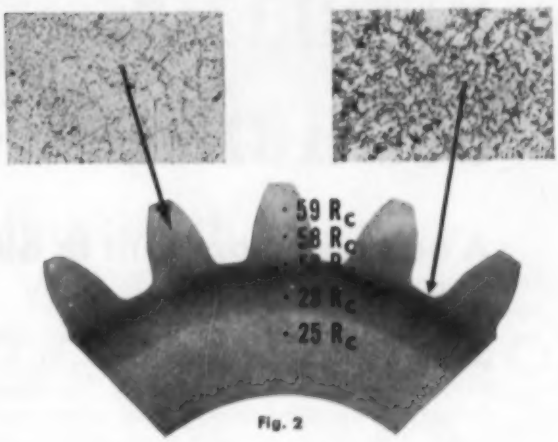

Fig. 2

at the surface. The high hardness over the tooth surface prevents wear, or removal of metal from the surface. Distortion is minimized by controlling the heat to limit hardening to these critical areas only.

Two types of burners are available to provide versatility with gas-air flame hardening. For heating large areas, radiant cup burners provide rapid heat transfer rates to the work-pieces by radiation from the highly incandescent ceramic cup surface and by convected heat of the hot gases without flame impingement. For localized heating, "Super-heat" type burners effect heat transfer by the convection effect of high velocity combustion gases issuing from a restricted outlet slot in the burner.

Both types of burners use premixed gas-air, supplied by a Combustion Controller, and no bottled oxygen is required.

Selas Corporation of America
Philadelphia 34, Pa.

what's new at BRISTOL...

SERIES 536 INDICATING

Free-Vane® Electronic Pyrometer Controllers

A new development in automatic temperature control

featuring...

● **A UNIQUE ELECTRONIC CONTROL SYSTEM, which gives a new quality of automatic control.** The controller is extremely stable, rugged, and sensitive. Very minute changes in the measured quantity at the control point (less than 0.003" on the scale) closes or opens the Thyratron-operated relay with positive trigger action, making it impossible for the relay to flutter or chatter. Control action is unaffected by changes in ambient temperature, line voltage, or wide variations in tube characteristics.

● **A NEW MILLIVOLTMETER MECHANISM for greater accuracy.** High-torque, rugged, jeweled mechanism has 30 ohm coil, Alnico 5 magnet, a sensitivity of 15 ohms per millivolt. All ranges are critically or over damped.

● **OUTSTANDING MECHANICAL DESIGN for easy installation, interchangeability, and simplified servicing.** All units, including pyrometer unit, electronic control unit, and proportional-input unit are separate. The electronic control and proportional-input units plug in. No routine adjusting or attention needed. Series 536 Indicating Free-Vane Electronic Pyrometer Controllers are available as thermocouple and radiation pyrometers in ranges up to 4000° F. for L, H, LH, HOH, and LNH control and for L and H with proportional input control. Write for Bulletin P1248. The Bristol Company, 106 Bristol Road, Waterbury 20, Connecticut. 3.10

LOOK FOR OUTSTANDING NEW DEVELOPMENTS FROM BRISTOL

BRISTOL

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AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

IN POWDER METALLURGY . . . IT'S AMPLEX

Pour Water and Gasoline in this Tank— and the Car Will Run!

The OILITE® permanent metal filter makes this gas tank different from that of most cars. Installed as standard equipment in all Chrysler-built cars since World War II, it not only prevents water from entering the fuel line but keeps out all foreign particles.

Army Ordnance tests demonstrated its effectiveness. Experimental installations were made in a number of Army trucks using—(1) standard tube fuel intake (with filter at carburetor end of fuel line) (2) floating filter (3) OILITE filter.

Two pints of ice crystals were put in the trucks' fuel tanks. Those with the standard tube failed to operate after 10 seconds. Trucks with floating filters stopped after 14 minutes, while those equipped with OILITE filters continued operating indefinitely without interruption, providing a steady flow of clean gasoline.

OILITE fuel filters are good for the life of the car. The filter allows ample flow even with 98% of the pores blocked. Tin plating prevents excessive gum deposits while the sloshing action in the tank keeps the surface clean.

OILITE permanent metal filters can help you in many ways. They are unusually successful for depth filtering, diffusing, metering, separating and flame arresting.

The engineering facilities of Amplex and Chrysler, unmatched in the powder metal industry, are ready to assist you. Call or write today for information.

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IT'S NEW! IT'S FREE!

First complete information on powder metal bearings, finished machine parts, filters and special parts. 48 pgs. Write for OILITE Engineering Manual E-55.

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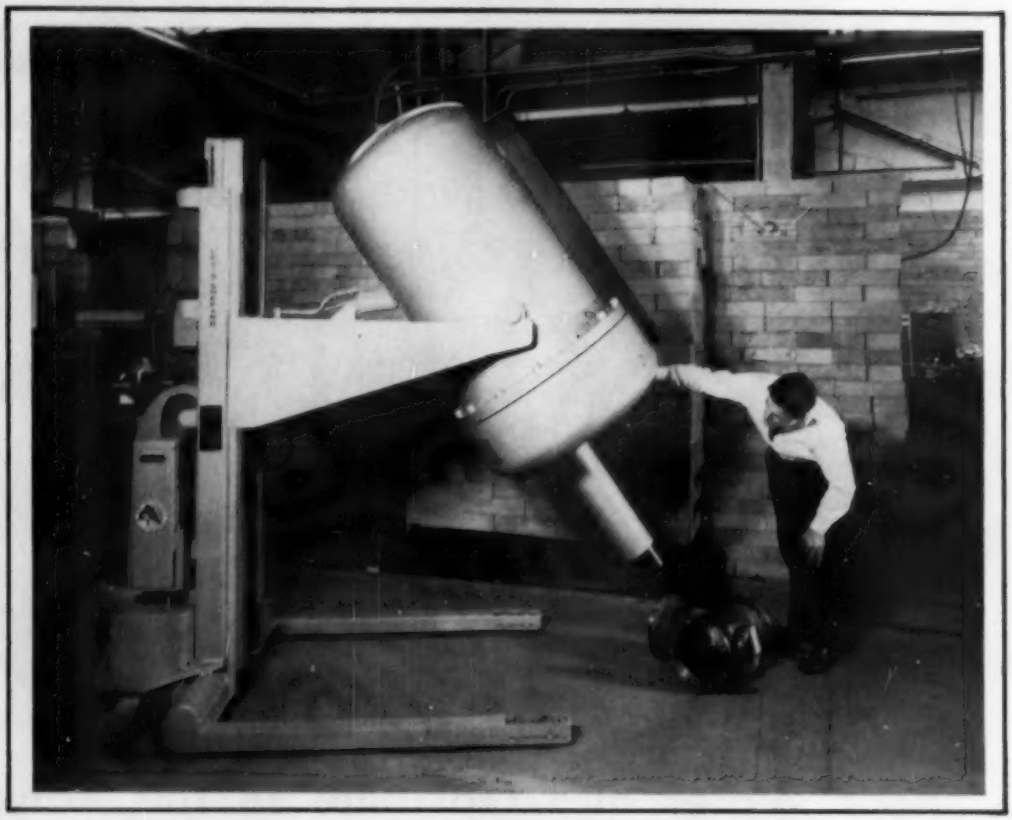
THROUGH THICK OR THIN–

HIGH QUALITY RADIOGRAPHY



Whether your radiographic problem involves metal sections 5 inches thick or ⅛ inch thin, HIGH VOLTAGE'S new Model JR Van de Graaff will yield radiographs of unmatched clarity on a production basis. No other industrial x-ray equipment has ever provided such versatility.

The JR is the only completely transportable source of one-million-volt x-rays available. It can be installed on a newly developed mobile motorized mount or located permanently in the smallest space at the lowest cost on any x-ray generator in its energy range.

A point source of x-rays less than 1 mm in diameter, substantial savings in set-up time, a power requirement of only 2 KVA – all these characteristics add up to low-cost, accurate radiography.

If you'd like additional information about this new Van de Graaff, write for Bulletin JR.

HIGH VOLTAGE ENGINEERING CORPORATION

7 UNIVERSITY ROAD CAMBRIDGE 38, MASSACHUSETTS

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

TO CAST?—OR NOT TO CAST? IS THAT YOUR QUESTION?

Objective approach to the CORRECT ANSWER, the optimum SOLUTION, begins with (A) ENGINEERING EVALUATION of YOUR JOB, in terms of (1) Parts treated, (2) Quality, UNIFORMITY, and production, expected, and attainable. (3) handling, furnace, and all operating factors, and VARIABLES. (B) ENGINEERING EVALUATION of all INTEGRATED Design-Process, Metallurgical, and Economic factors, beneficially applicable to FUNCTIONAL-DEPENDABLE,—Lowest-Cost of Product and Maintenance on YOUR JOB. (C) From this *technically, and logically* SOUND Approach, on the UNIQUE basis of 35 years of *unequalled* EXPERIENCE, and *unprecedented* research and development, GENERAL ALLOYS ENGINEERS develop specific designs, and, if indicated,—*alternate proposals* for execution by G. A. New England CRAFTSMEN, by processes *best applicable*. Cast, wrought and composite fabrication as INDICATED FOR OPTIMUM SOLUTION of YOUR SPECIFIC requirements, are recommended.

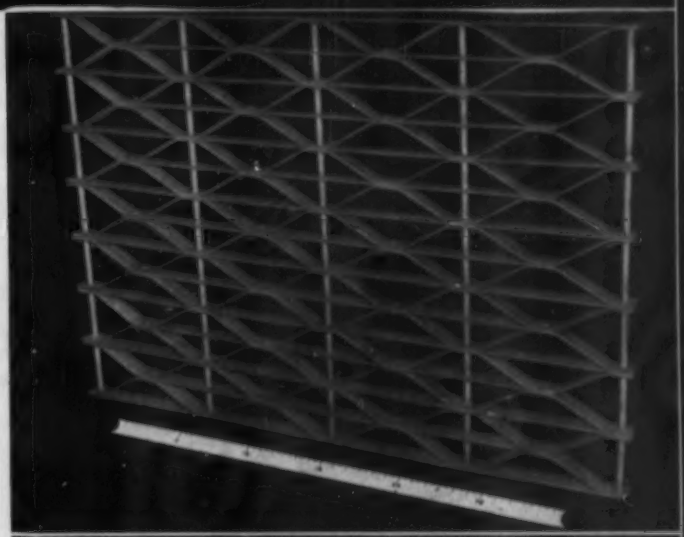
GENERAL ALLOYS COMPANY, a national ENGINEERING organization, should not be confused with "Foundries", and "Fabricators". We began designing and producing castings, wrought and fabricated Heat-and-Corrosion-Resistant Alloys EXCLUSIVELY in 1919.

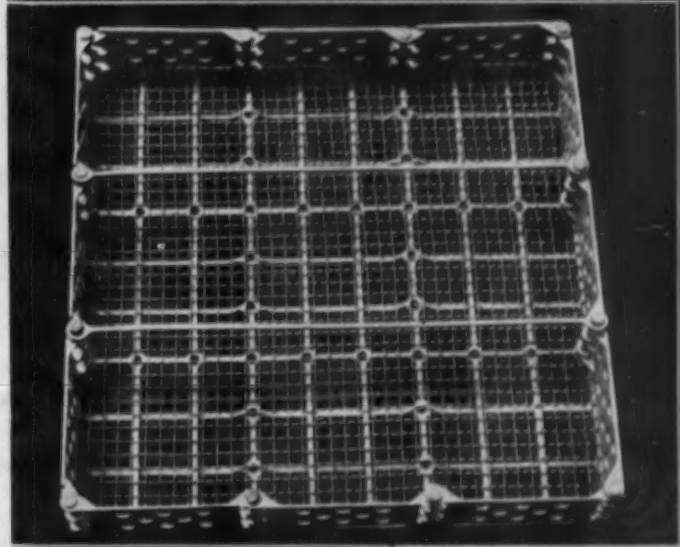
We DESIGN about 95% of our product for specific applications. REMEMBER that all metals *begin with a casting*, and that a *weld is a casting*. G. A. control of process from raw materials to finished product is an ADVANTAGE.

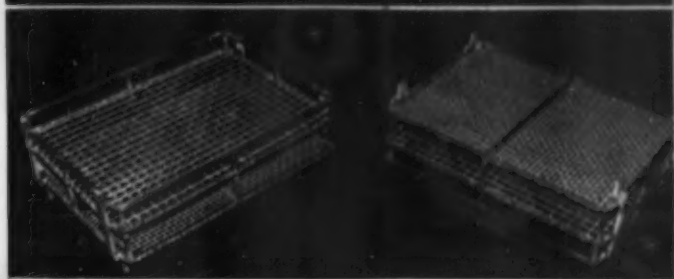
CAST, SHEET, ROD, BAR, STRIP AND WIRE, WROUGHT AND COMPOSITE G. A. *FABRICATIONS* ARE ILLUSTRATED. They are, (top-to-bottom), (1) Q-Alloy "Serpentine" furnace tray—Ford Motor Co. (2) X-ite "Thermo-flex" tray—Auburn Clutch Co. (3) Q-Alloy-B. Lever-shaft gas-carburizing fixture for mounting on cast tray-Chrysler Motor Co. (4) Composite furnace combustion-tube, 3/16" welded Inconel straight tube "Tough spots", (bend and burner-end) are G. A. Castings.

G. A. FABRICATING DEPARTMENT HAS BEEN GREATLY ENLARGED TO MEET DEMAND for ENGINEERED, Metallurgy - Process CONTROLLED ALLOY Products, which G. A. EXPERIENCE, and 100% ALLOY organization INSURES.

Inquiries for ENGINEERED Heat and Corrosion resistant Castings and Fabrications Solicited.



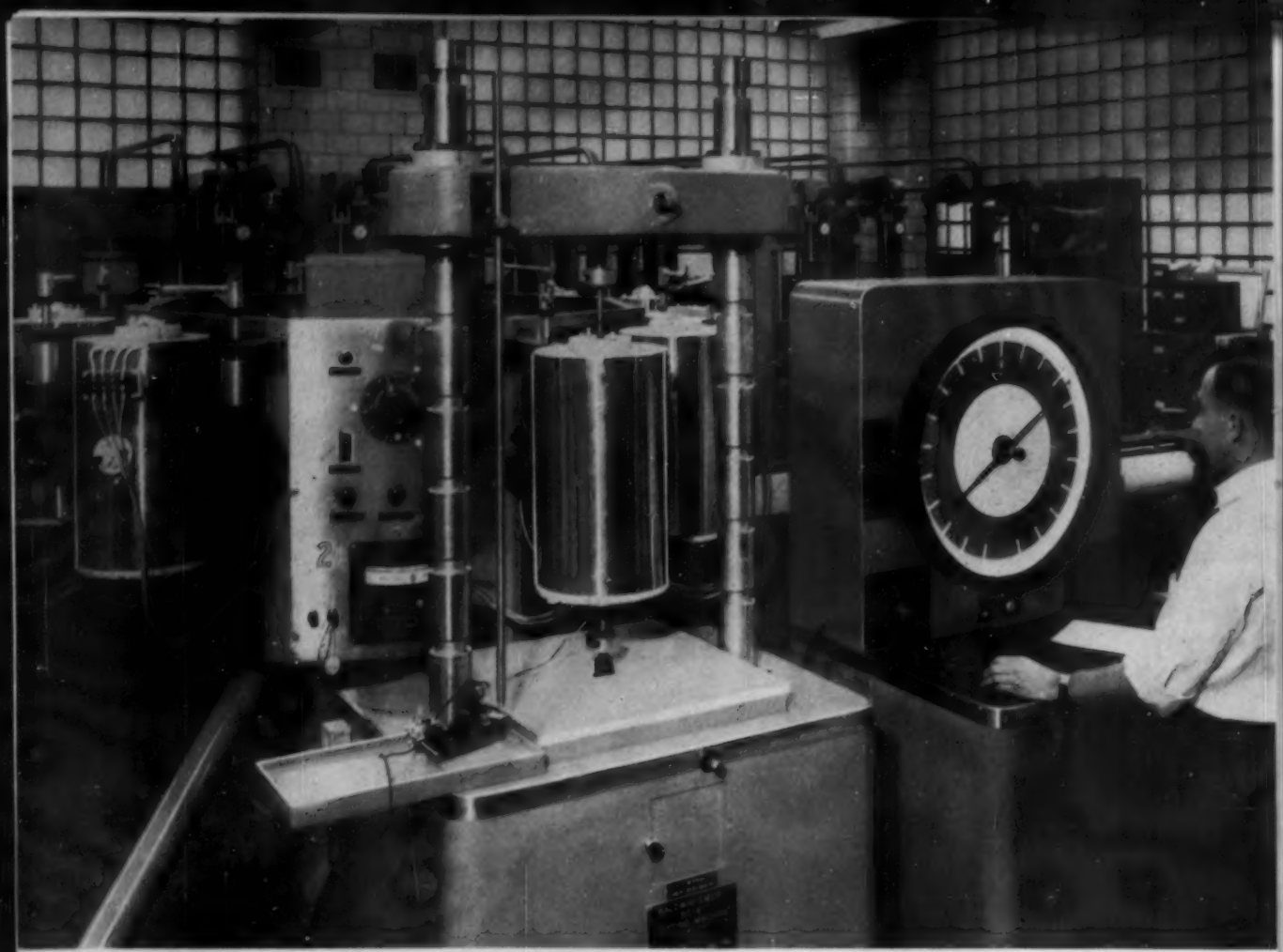




GENERAL ALLOYS COMPANY

405 W. First St., Boston, Mass.

Offices and Representatives in Principal Cities.



New "all-electric" Baldwin SR-4® Testing Machine at Universal-Cyclops

measures electrically both tensional loads and strain on "SUPER ALLOYS" at 2200° F.

In the modern laboratory of Universal-Cyclops Steel Corporation, Bridgeville, Pa., "super alloys" for high temperature service are being tested at 2200° F. by a unique new Baldwin machine. Model FGT SR-4 is electrically powered and measures electrically both applied tensional loads and resulting specimen strain.

SR-4 load cells at the bases of the two columns sense loads up to 50,000 lb. in tension or compression. These cells control both the load indicating pointer and the recorder pen movement.

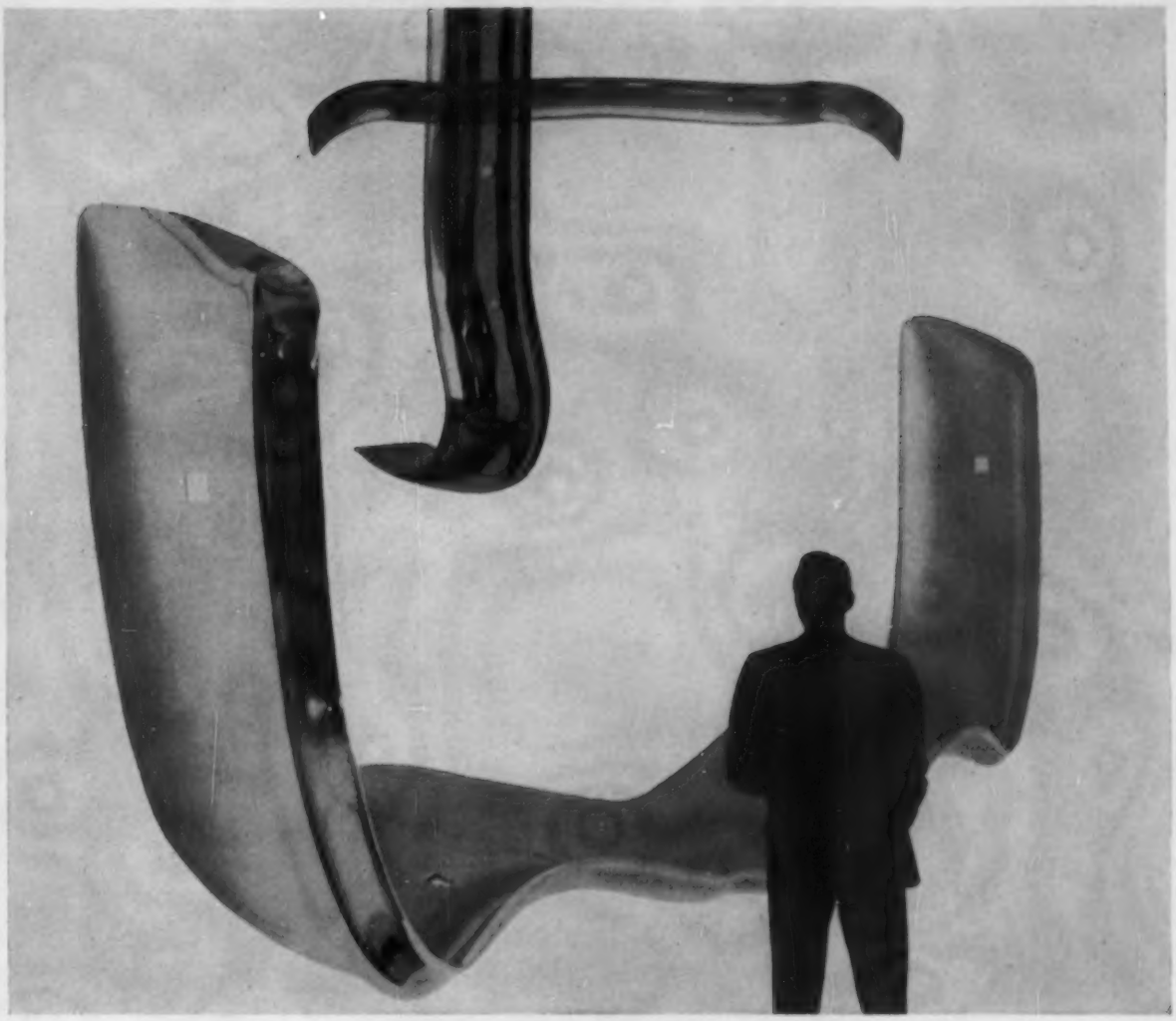
Strains of 0.160 in. diameter, 1-in. gage length button-head specimens, measured by a SR-4 type extensometer are transmitted electrically to the recorder. Close control of the strain rate is an important factor in these high temperature tests. The FGT's motor drive's loading control can be regulated to vary testing speeds from 0.025 to 9.0 in. per minute.

Univeral Cyclops is using an ingenious rotary jig to speed up greatly the frequency of tests at elevated temperatures. Eight electric furnaces on this jig heat test specimens simultaneously. Each is swung into testing position with a minimum of delay. This revolutionary new testing machine can give you automatic load reversal, creep tests, stress relaxation tests, shock tests as well as simple tension and compression. For complete detailed information please write today for Bulletin No. 4206. Address Department 2724, Baldwin-Lima-Hamilton Corporation, Philadelphia 42, Pa.

BALDWIN BLH LIMA-HAMILTON

TESTING HEADQUARTERS

BALDWIN-LIMA-HAMILTON



Deep-draw costs come down—fast . . .

. . . thanks to the Pennsalt FOS Process. Any way you look at it, severe deep-drawing of automobile parts, such as these bumpers, is being made easier, cleaner, and more economical by modern Pennsalt drawing lubricants. Steel strip comes to the dies pre-coated with Foscoat 40 and Drawcote. Foscoat is a phosphatizing compound that prepares the work for the appropriate dry FOS lubricant; Drawcote (product of Pennsalt's newly-acquired Gilron Division) forms a dry, homogeneous protective and lubricating film to speed the most severe drawing operation.

With these two Pennsalt chemicals, the auto industry is deep-drawing, stamping, and extruding steel parts at much lower cost than was previously possible. Die life is greatly increased. Plating is smoother with less finish buffing, because drawn parts are freed from die seizures, scratching, and irregularities. And these modern *dry* lubricants make the press shop a cleaner, safer place to work in.

For the severest deep draws in ferrous metals, the combination of Foscoat and Drawcote is literally working wonders. For lighter draws, and for certain special applications, Drawcote *alone* is recommended. With the full FOS line (Fosclean, Fosrinse,® Fospray, Foscoat,® Drawcote,® Foslube®), Pennsalt offers a process to meet every ferrous metal drawing requirement. And what is more, metal pre-coated with the FOS Process seldom needs re-coating for the next press stages.

For information on the Pennsalt FOS Process to fit *your* drawing or stamping needs, send blueprints of parts you're cold-forming, and give us details on type of steel, length of run. No obligation, of course. Customer Service Department, Pennsylvania Salt Manufacturing Company, 1102 Widener Building, Philadelphia 7, Pa.

FOSCLEAN AND FOSPRAY ARE TRADEMARKS OF PENNSYLVANIA SALT MFG. CO.

Chemical Progress Week May 16-21

Pennsalt Chemicals

Metals Engineering at

As described by K. R. Knoblauch, *Metals Industry Sales Manager*, Minneapolis-Honeywell Regulator Company, Industrial Division

"Every design and production decision we make is based primarily on analysis of the metals and engineering factors involved.

"In Product Development, for instance, our Metals Engineers not only recommend the metals and their sources, but also select ceramic materials and components. Our Metals Engineers in the Industrial Engineering and Raw Materials Departments then service the manufacturing stages, buying material acceptable to our metals engineering group as a

Inspecting a Brown *ElectroniK* multiple point strip chart recorder, which is undergoing final test in one of Honeywell's Philadelphia plants, are K. R. Knoblauch, Metals Industry Sales Manager; B. W. Smukler, Buyer of Raw Materials; A. F. Allwein, Development Engineer; G. E. Tranter, Industrial Engineer . . . all members of the American Society for Metals and readers of *Metal Progress*.

Minneapolis-Honeywell

whole, saying what and where it is to be purchased.

"Customers frequently ask us for assistance in the processing of metals, die castings, forgings and the like. Thus our metals engineering influence extends through all phases of metalworking, into heat treating, machining and finishing, in customers' plants as well as our own."

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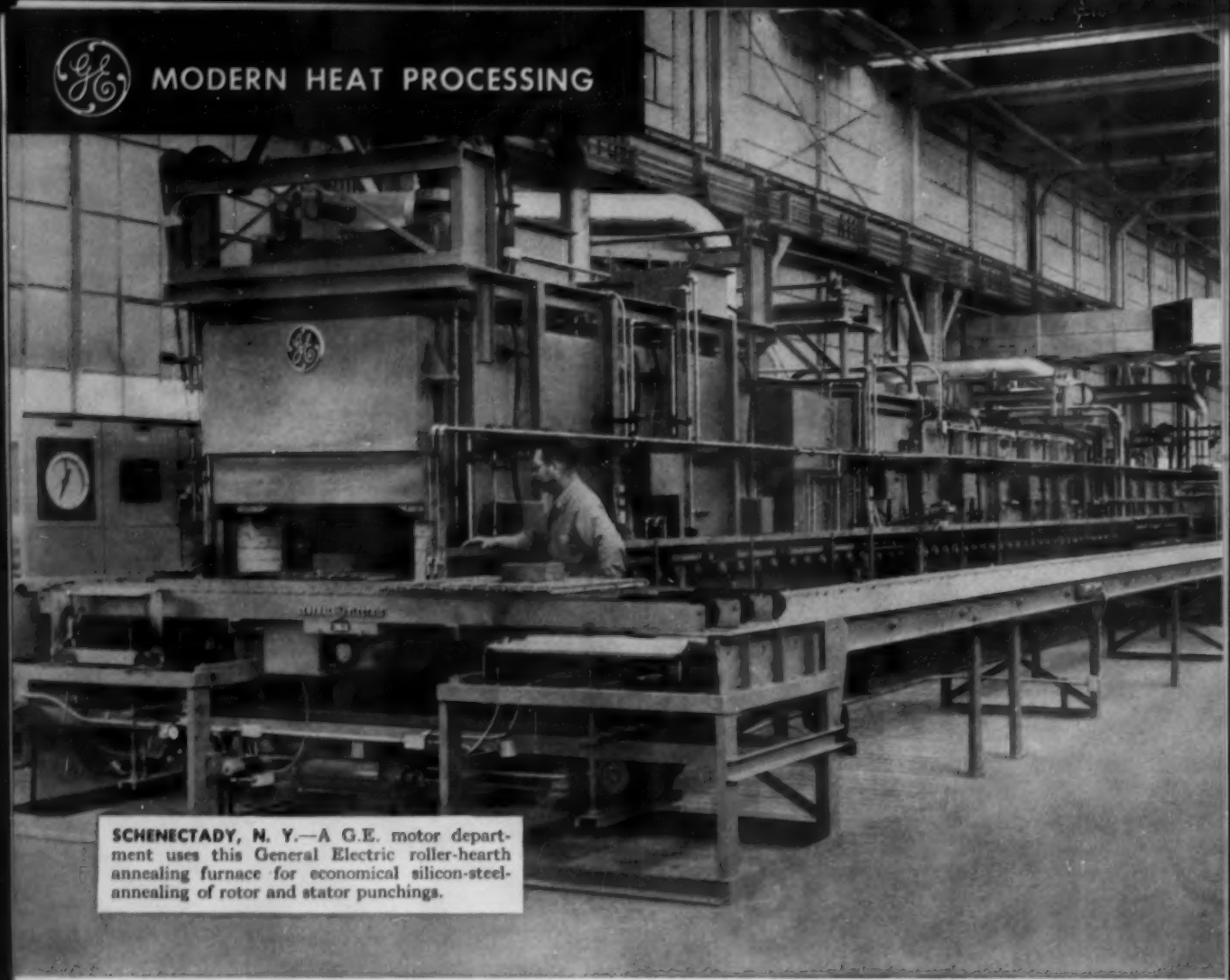
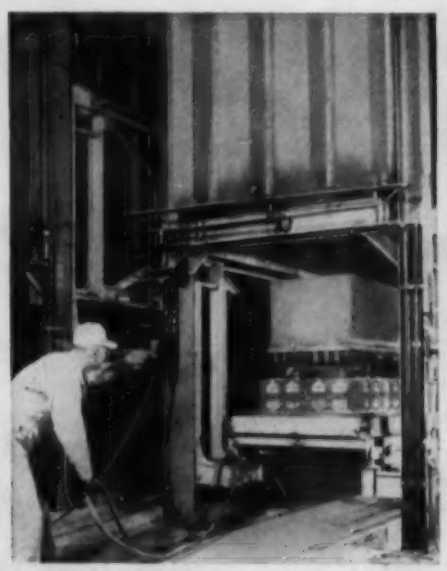
MODERN HEAT PROCESSING



SCHENECTADY, N. Y.—A G.E. motor department uses this General Electric roller-hearth annealing furnace for economical silicon-steel-annealing of rotor and stator punchings.

WIDE VARIETY OF G-E ANNEALING FURNACES NOW LETS YOU ANNEAL SILICON STEEL RIGHT IN YOUR OWN PLANT

Take a tip from General Electric, user of about 25% of the country's production of silicon steel—you can cut costs by annealing your own silicon steel. There's a General Electric silicon steel annealing furnace for nearly every type of annealing application—large or small. For example, the furnaces at right are located in different G.E. plants, each handling a different size silicon-steel-annealing job — *economically.*



G-E ELEVATOR FURNACE at Rome, Ga. plant is used for high temperature annealing of transformer cores—furnace fits in minimum space.

G-E BELL FURNACE, Waynesboro, Va. Low-production unit anneals machine parts at low cost.

PROBLEM:

Annealing silicon steel in an automated setup

SOLUTION:

G-E roller hearth furnace anneals stator punchings and weld in one pass, cuts costs

A roller hearth furnace in the new automated production line for one of G.E.'s motor departments anneals 1500 pounds of rotor and stator punchings an hour—helps produce a Tri-Clad* 55 motor (7½ to 35 hp) every 2½ minutes. The stator punchings and weld are annealed at the same time. This eliminates the cost and time involved in making two passes through the furnace. Only one man is needed to oversee the complete annealing operation.

IN ADDITION TO G-E furnace quality, here are the advantages you receive when you deal with G.E. on silicon steel annealing:

(1) TECHNICAL KNOWLEDGE—G-E research helped pioneer the development of silicon steel for improved magnetic properties.

*Reg. trademark of General Electric Company.

(2) EXPERIENCED USER—G.E. uses about 25% of the total production of silicon steel.

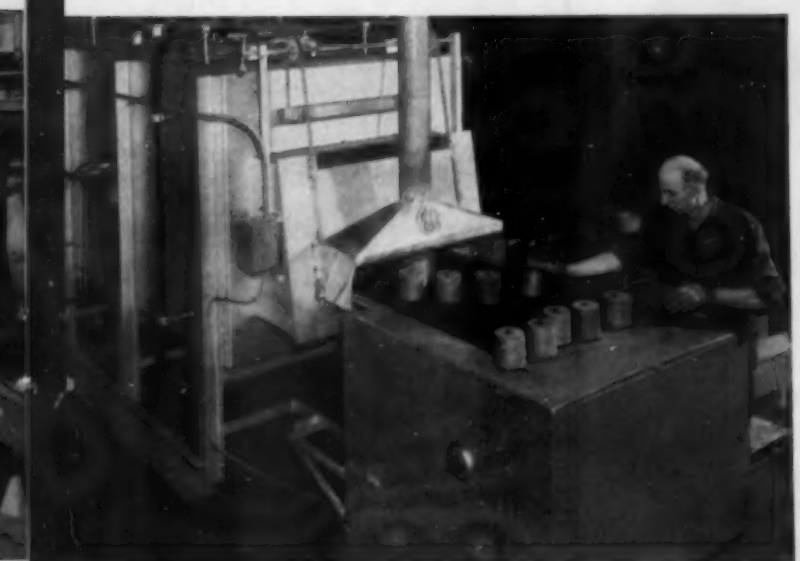
(3) EXPERIENCED BUILDER—G.E. offers a complete line of furnace and control equipment for your silicon steel annealing.

(4) APPLICATION HELP—plus installation supervision—assure you of the most efficient furnace installation.

(5) MAINTENANCE SERVICE—Nearly 200 G-E service shops, located throughout the country, are ready to help you 24 hours a day.

ASK FOR THE SERVICES of your local G-E Apparatus Sales Representative in assessing the economies of annealing silicon steel in your plant. Just call your nearby General Electric Apparatus Sales Office.

GENERAL ELECTRIC



G-E MESH-BELT FURNACE located at Ft. Wayne, Ind. plant blue-anneals rotor laminations. Ideal for medium production, the mesh-belt furnace is flexible for use over a wide range of temperatures and speed.

FREE PROCESS BULLETINS

Please send me the Modern Heat Processing bulletins I have checked below.

- ☐ Protective Atmospheres, GEA-5907
- ☐ Annealing Malleable Iron, GEA-5797
- ☐ Furnace and Induction Brazing, GEA-5889
- ☐ Wire Enameling, GEA-6179
- ☐ Heat-treating Aluminum, GEA-5912
- ☐ Forging with Induction Heat, GEA-5983

General Electric Company
Apparatus Sales Division, Section B721-4
Schenectady 5, New York

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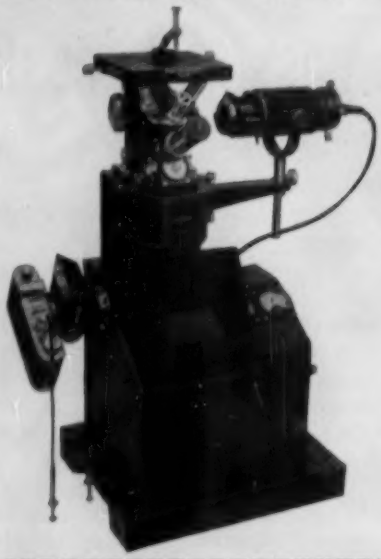
We invite you to try any model in your own laboratory for 10 days at no cost or obligation!



UNITRON METALLOGRAPH and UNIVERSAL CAMERA Microscope, New Model U-11

- For visual observation, measurement, and photography of both opaque and transparent specimens.
- Bright field, dark field, and polarized illumination.
- Revolving nosepiece with 6 objective lenses, 4 photographic eyepieces, 3 visual eyepieces. Coated optics. Magnification range: 25-2000X.
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- Transmitted light accessories for transparent specimens included.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Many other important features and accessories including calibrated polarizing apparatus, filters, micrometer eyepieces, film holders, etc. Cabinet.
- 58 mm camera attachment, low power (5-40X) accessories, and binocular eyepiece available at extra cost.

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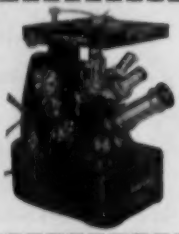

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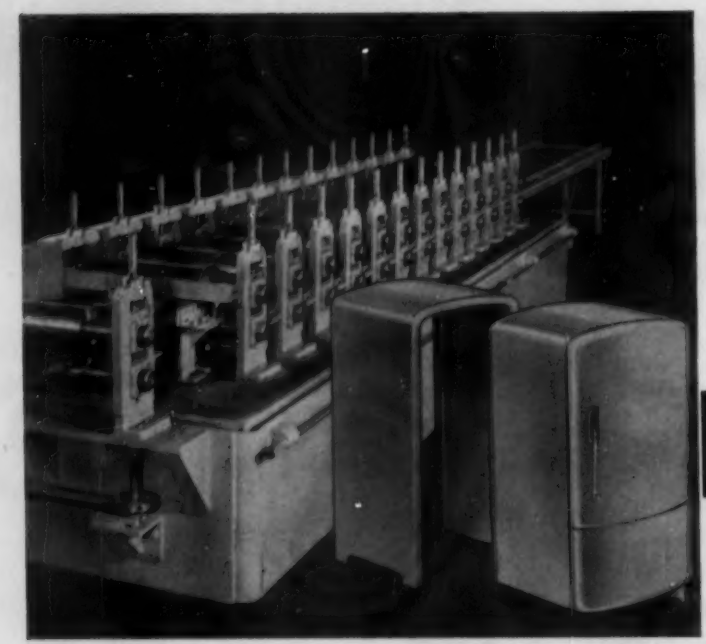

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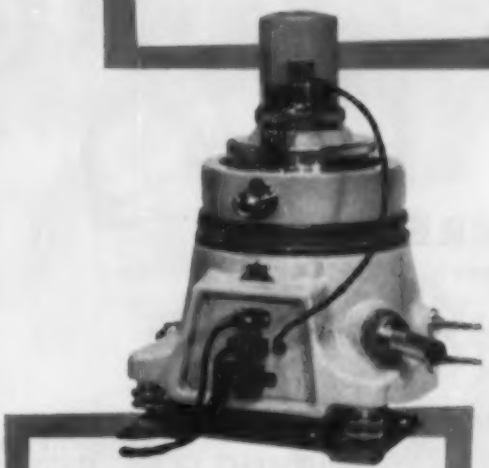

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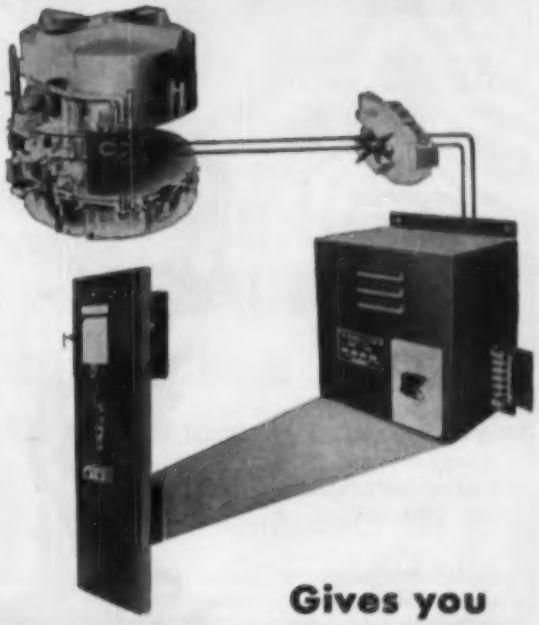

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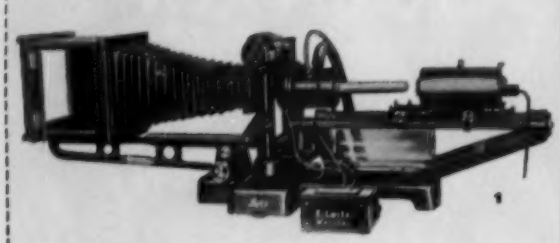

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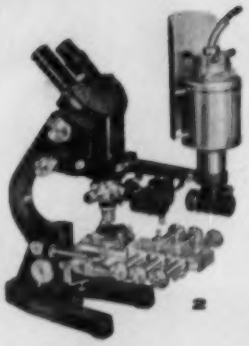

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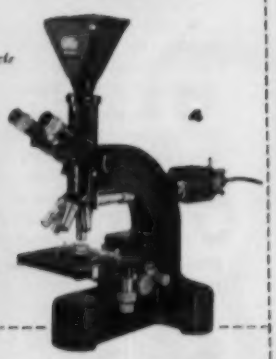

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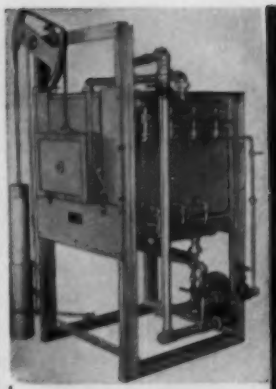

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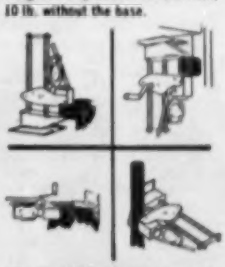

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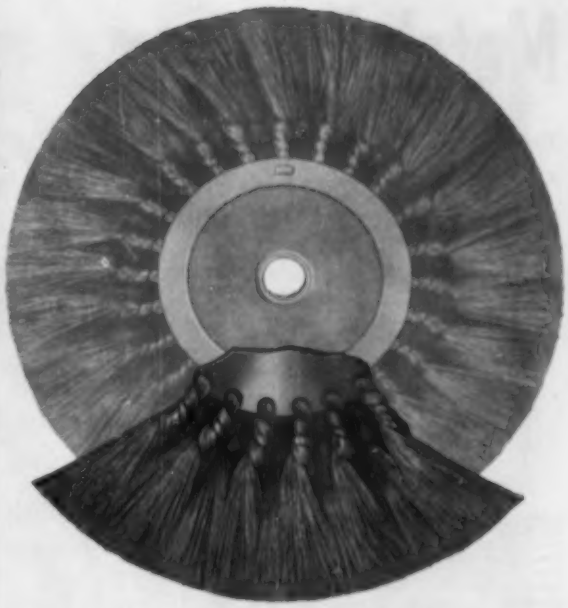

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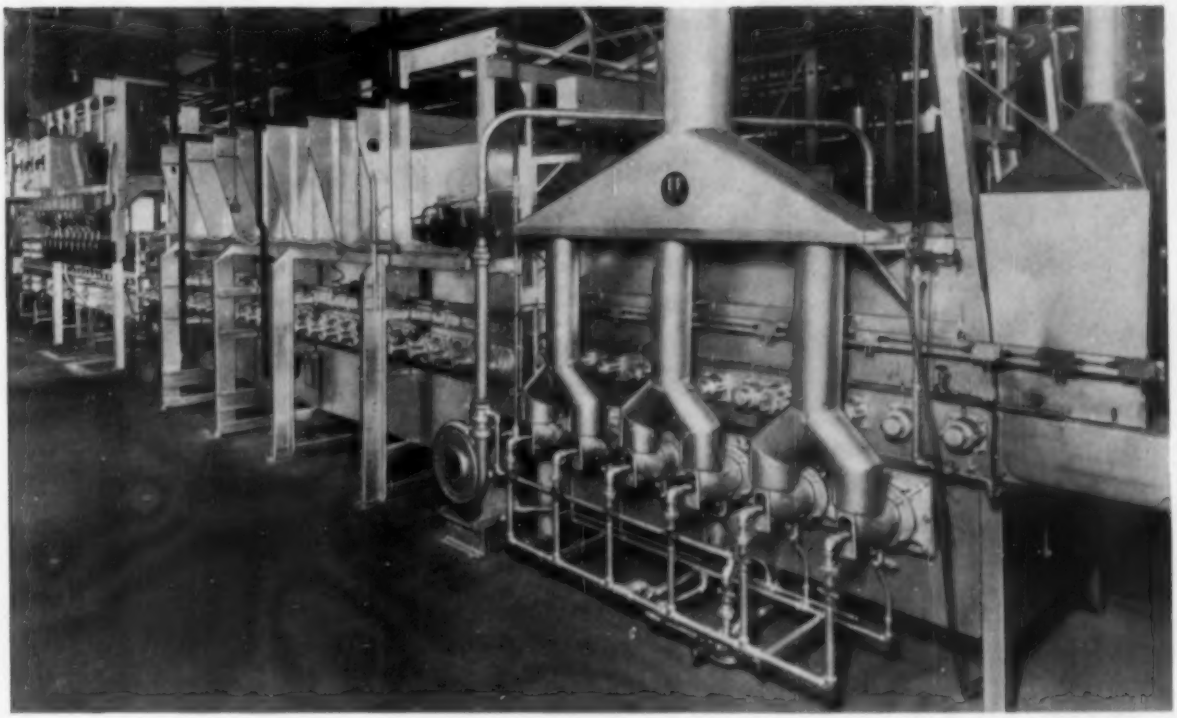

EF combination gas fired radiant tube and electrically heated roller hearth large capacity furnace for sintering metal powder parts at temperatures up to 2050° F.

Sintering Furnaces

For Ferrous and Non-Ferrous Powder Products Provide for–

- lowest cost per pound for the sintering operation.
- maximum uniformity of size for the sintered products.
- maximum pounds of quality product per dollar of investment.

We have built many sizes and types of furnaces for processing a wide variety of ferrous and non-ferrous metal powder products—also continuous equipment for bonding metal powders to strip and for other processes.

Long experience with special atmospheres, metal powders and all heat processing phases in connection with powder metallurgy has enabled EF engineers to develop and install equipment for producing some rather outstanding results.

With our extensive experience and complete manufacturing facilities we are in position to build the size and type of equipment to fit your specific requirements.

We would like to discuss some of our latest furnace developments with you, if interested.

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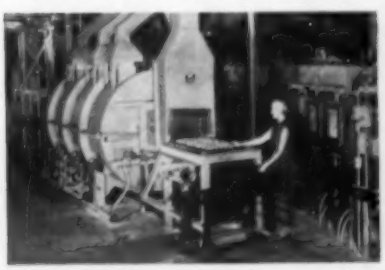
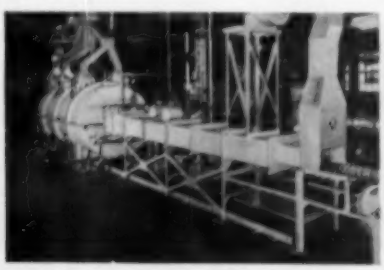
Gas Fired, Oil Fired and Electric Furnaces
—For Any Process, Product or Production.



EF gas fired muffle type continuous furnace, one of several types we build for sintering non-ferrous and iron powder products at temperatures up to 2050° F.



Completed sintered parts are discharged—continuously—uniform in size, finish and treatment—requiring no machining or further processing.

This type available for various treatments including sintering metal powder products, brazing and other processes at temperatures up to 2050° F.

When the Chips are down

4140 LEADED

These chips taken from a single point turning on a turret lathe are visible proof of the better chip formation and superior machining qualities of leaded Aristoloy.

4140 UNLEADED

Under the same conditions single point turning of unleaded 4140 on a turret lathe produced these long continuous chips.

● It's a good bet you can cut machining costs by specifying leaded Aristoloy or Ledloy* in your plant. The addition of lead to steel acts as a lubricant and substantially reduces friction between chip and tool. This permits higher machining speeds and faster feeds. Tools last longer and the finished part has a finer, smoother finish. The results of our own testing and the experience of dozens of enthusiastic users also indicate that the lead addition which works this dramatic miracle in no way affects basic steel characteristics. Heat treating, tensile strength ductility, and impact strength are unchanged. Neither does the lead present a health hazard for normal forging or machining operations.

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If you would like specific information about application of lead steel to your product get in touch with your nearest Copperweld office or write us today.

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